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Assessment of the capacity for flood monitoring and early warning in enlargement and Eastern/Southern Neighbourhood countries of the European Union

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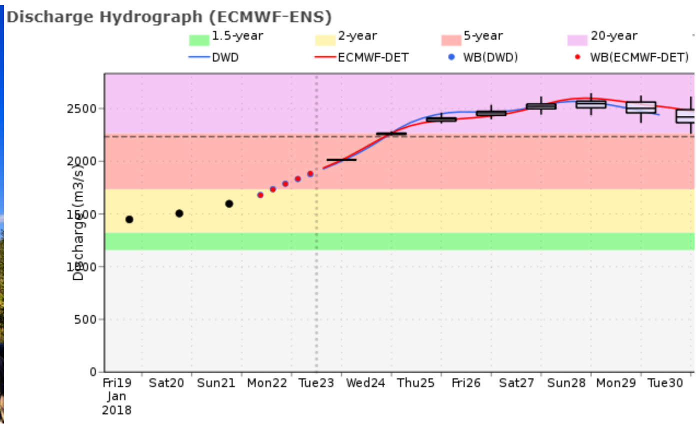

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Assessment of the capacity for flood monitoring and early warning in EU neighbouring countries
Flooding is a natural disaster that can damage large areas in the vicinity of rivers, and in the case of flash floods, also in the vicinity of smaller streams. This report presents an assessment of the capacity for flood monitoring and early flood warning for 17 of EUs neighbouring countries. Many possibilities for improvements were identified, both on a national and regional level. Some important recommendations include: i) maintenance has to be considered when funding improvements of measurement networks; ii) training of staff is highly demanded in all countries; and iii) international efforts for meteorological and hydrological modelling should be encouraged.

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Foreword

Flooding is a natural disaster that can damage large areas in the vicinity of rivers, and in the case of flash floods, also in the vicinity of smaller streams. People, properties and agricultural land can be affected. The EU supports Member States together with European Neighbourhood Policy (ENP) and Southern Neighbourhood Policy (SNP) countries when disasters strike, and also helps the countries with prevention and preparedness for disasters.

This report presents the results of an assessment of the capacity for flood monitoring and early flood warning systems in European Union enlargement countries and the eastern and southern neighbourhood countries. It facilitates the mapping of the countries' current capabilities and their needs in terms of infrastructure and monitoring and forecasting capabilities in order to establish effective systems.

The outcome of the assessment illustrates the gaps in flood early warning and monitoring system and recommends areas which should be prioritised to strengthen the resilience against floods and reduce the impacts on society.

The assessment is based on contributions from national experts for each country. A summary of each of the national reports is given in the Annex of this report.

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Executive summary

Flooding is a natural disaster that can damage large areas in the vicinity of rivers, and in the case of flash floods, also in the vicinity of smaller streams. The Global Risks Report 2017 ([1]) lists extreme weather events, of which flooding is the main risk in most countries, as the risk with the second highest potential impact and the highest likelihood of occurrence. It furthermore seems likely that climate change will aggravate flood impacts in many regions.

This report presents an assessment of the capacity for flood monitoring and early flood warning in 17 of the 23 countries which belong to the Eastern and Southern Neighbourhood Policy of the European Union and the enlargement candidate countries. Many of these receive external funding to improve their systems, but this is often on an ad hoc basis and through individual projects. The Eastern Neighbourhood countries include Belarus, Ukraine, Moldova, Georgia, Azerbaijan and Armenia, whereas the enlargement countries are Albania, Bosnia and Herzegovina, Kosovo ([2]), the former Yugoslav Republic of Macedonia, Montenegro, Serbia and Turkey. All of these are included in this assessment. The Southern Neighbourhood Policy countries include Egypt, Israel, Jordan, Morocco ([3]), Algeria, Lebanon, Libya, Palestine ([4]), Syria and Tunisia. The first four of these are included in the assessment.

Policy context

The European Neighbourhood Policy is an instrument of the European Union (EU) for creating closer relationships with countries east and south of the EU territory. The EU can offer financial assistance to the countries through the European Neighbourhood Instrument (ENI), depending on conditions of government reform, economic reform and other issues. EU and the partner countries work both bilaterally and regionally. In addition, a large number of funds are available for candidate countries, within the Instrument for Pre-accession framework.

A thorough objective assessment of the flood monitoring and early warning capacity is crucial for national and regional authorities to identify strengths, gaps and cooperation opportunities to place future investments strategically with the aim to quickly improve the protection of citizens, assets and environment.

It is also important for the EU Civil Protection Mechanism, which fosters cooperation among national civil protection authorities across Europe. Currently all EU Member States are included, additionally Serbia, the former Yugoslav Republic of Macedonia and Turkey from the countries in this assessment. All countries can ask for help from the EU Civil Protection Mechanism.

The enlargement countries will have to follow the EU Floods Directive (EU, 2007) as a part of their preparations for joining the EU. Some of the chapters of the directive are covered by this report. For the other countries, it will be of interest to see the development level of comparable countries.

([1]) http://www3.weforum.org/docs/GRR17_Report_web.pdf

([2]) References to Kosovo are without prejudice to positions on status. They are in line with United Nations Security Council Resolution 1244/99 and the opinion by the International Court of Justice on the Kosovo declaration of independence.

([3]) References to Morocco in this report includes the area of Western Sahara. This is without any prejudice to positions on the status. However, the area is under the responsibility of the Meteorological Department of Morocco, and all numbers from the department include Western Sahara.

([4]) This designation shall not be construed as recognition of a State of Palestine and is without prejudice to the individual positions of the Member States on this issue.

Main findings and key conclusions

The capacity for flood monitoring and modelling is highly different in the different countries. Some countries have a large number of automatic meteorological and hydrological stations, others are still relying on manual stations with infrequent reporting to the main office. Some countries have good modelling tools for many watersheds, whereas other countries are relying on expert interpretation of weather forecasts and the most recent observations. Also, the size of the services is highly different. Many of the numbers might not be directly comparable, and depend on local/central organisation and on monitoring efforts, but they range from a few 10s of staff to several thousands.

All experts were asked to give priorities to improving different components of their countries' systems for monitoring and early warning of floods. Some conclusions and priorities for improvements will only be relevant on a national scale, but more general conclusions about challenges and limitations that affect several countries can be derived from this assessment

First of all, many services gave a high priority to improving their staff skills in relation to such systems. Developing, implementing and maintaining flood early warning and monitoring systems requires a wide range of highly specific skills ranging from hydrology and meteorology to geography and ICT. Many services mention lack of IT skills in general, and lack of skills to develop and run a forecasting model. However, the specific curricula required are sometimes not available in the national education system or are very general. New staff can to some degree improve the situation, but existing staff will also need courses for updating and improving their skills. The services in some of the countries could improve the connections with universities, for developing better curricula. Language is an issue, particularly for older staff, as relevant courses and information is often only available in English. When developing courses and training for a service, it should also be considered if staff from neighbouring countries with similar languages could participate.

A second issue is the funding of new stations, which for many of the countries has come from external donors. Whereas such funding is welcome, it is not uncommon that the countries will struggle with maintenance, as this is in most cases not included in the support.

From the information provided by the experts a number of key conclusions can be drawn.

- Countries should be encouraged to develop a coherent medium- to long-term management investment plan and channel the funding according to a plan and not on ad hoc basis. All relevant authorities should be included, and the work should ideally also be done in collaboration with neighbouring countries.
- Transnational operational modelling should be fostered, particularly for meteorological and hydrological forecasting. Joint projects are not only beneficial for the particular forecasting model, but also for cooperation and information exchange between national services.
- Investments in improving monitoring networks should only be done if maintenance costs can be covered, installation of stations with low maintenance should be emphasised. Fewer but reliable stations can be better than many stations that fail after a short period due to lack of maintenance.
- There is a high need and demand for training and capacity building in all areas (monitoring, forecasting, modelling, etc.) by almost all countries.
- Standardisation — there should not be different standards from one authority to another, or from one river basin to another within the same country as this would then make exchange and intelligent use of equipment and sharing of data more difficult
- Countries with risk of flash floods should install/upgrade rainfall radars and get expertise to operate them. The radars should cover a larger area than the actual region of interest to be able to detect the arrival of potential heavy precipitation systems. Building a network or collaboration with neighbouring countries to provide access or share the relevant radar information is therefore important.

- Good results can for many watersheds be achieved with simpler models, it is often not necessary to implement highly complex models.
- Not all infrastructure needs to be hosted by the services, cloud services could be used more frequently.

Related and future JRC work

The JRC has been providing support to flood risk management related topics since several years. One of the most prominent activities in this area was the development of the European Flood Awareness System, which provides added value, complementary flood forecasting information to relevant national authorities and which is now included as a component of the Copernicus Emergency Management Service, managed by the JRC. In addition, the JRC is providing scientific policy support to the implementation of the Floods Directive as well as to DG ECHO's Emergency Response Coordination Centre and flood related EU Solidarity Fund requests. The flood modelling and risk assessment work contributes also to the EU's climate change adaptation strategy and is furthermore shared through the European Commission's Disaster Risk Management Knowledge Centre. Given that there is a high probability that the impact of floods will increase in Europe and globally due to climate change the JRC will continue to strengthen and support preparedness, prevention and response to floods at EU as well as national and local level.

Quick guide

This study is a summary of country reports assessing the capacity for flood monitoring and early warning in 17 of the countries neighbouring the EU. Country experts have summarised hydro-meteorological monitoring networks and forecasting capabilities in their countries.

The networks were analysed regarding station density, degree of automation and reporting frequency. Forecasting warning capabilities have been assessed based on access to regional or national meteorological forecasts, hydrological modelling capabilities and staff resources. In addition, the experts, together with hydro-meteorological services, have given priorities of potential improvements of the countries' capacities.

1 Introduction

Flooding is one of the most common and damaging types of natural disasters in Europe. In some cases it is the increased water level in rivers and lakes that cause the damage, in other cases the large amounts of water also moves violently, with erosion, leading to total destruction of buildings and removal of agricultural land as a possible consequence. All countries can to a smaller or larger degree be affected.

The Global Risks Report 2017 lists extreme weather events, of which flooding is the main risk in most countries, as the risk with the second highest potential impact. Whereas the highest risk (weapons of mass destruction) is coupled with low likelihood, extreme weather events also have the highest likelihood of happening. Climate change will most likely aggravate this (Alfieri et al., 2017).

Whereas the meteorological conditions cannot be controlled, preparedness and response to floods are essential to reduce the potential damages of flooding. An important part of increasing the resilience in many countries is to improve their capacity for flood and meteorological monitoring and early warning systems. Meteorological and flood records will give an indication of flood risk and help in developing flood forecasts. Real-time monitoring, access to meteorological forecasts and a capacity to issue qualitative or quantitative forecasts will give more time for evacuation, and in many cases, also for installation of temporary flood protection measures along rivers. Developing comprehensive national monitoring tools and early warning systems for flood response at local and regional level requires not only an effective monitoring infrastructure for hydro-meteorological variables, but also specific expertise, adequate IT and a solid administrative and legal framework amongst others. However, the state of these systems is highly diverse in different countries.

This report presents an assessment of the capacity for flood monitoring and early flood warning in European Union Enlargement countries and the Eastern and Southern Neighbourhood countries. Many of these receive external funding to improve their systems, but this is often on an ad hoc basis and through individual projects.

This report has been coordinated by the European Commission‘s Joint Research Centre (JRC). The authors of this report have all been asked to present the current situation in their countries of monitoring and warning systems based on a template prepared by the JRC. In this way, it is possible to compare the situation in different countries, to identify regions with similar possibilities for improvements, and possible problems with the current funding mechanisms.

There are altogether 23 countries among the enlargement countries and in the Eastern and Southern neighbourhood of the European Union. Nine of these belong to Europe, nine are in Asia or on the border between Asia and Europe, and the last five are in Africa, along the Mediterranean coast. In 17 of these countries, we were able to find an expert who was the main author of the country report. The experts were in most cases people employed either in hydrological or meteorological services. In some cases, they were external consultants who authored the reports based on information collected from the services.

The remaining countries as shown in Figure 1 could not be assessed either due to the current political situation or due to unavailability of relevant experts.

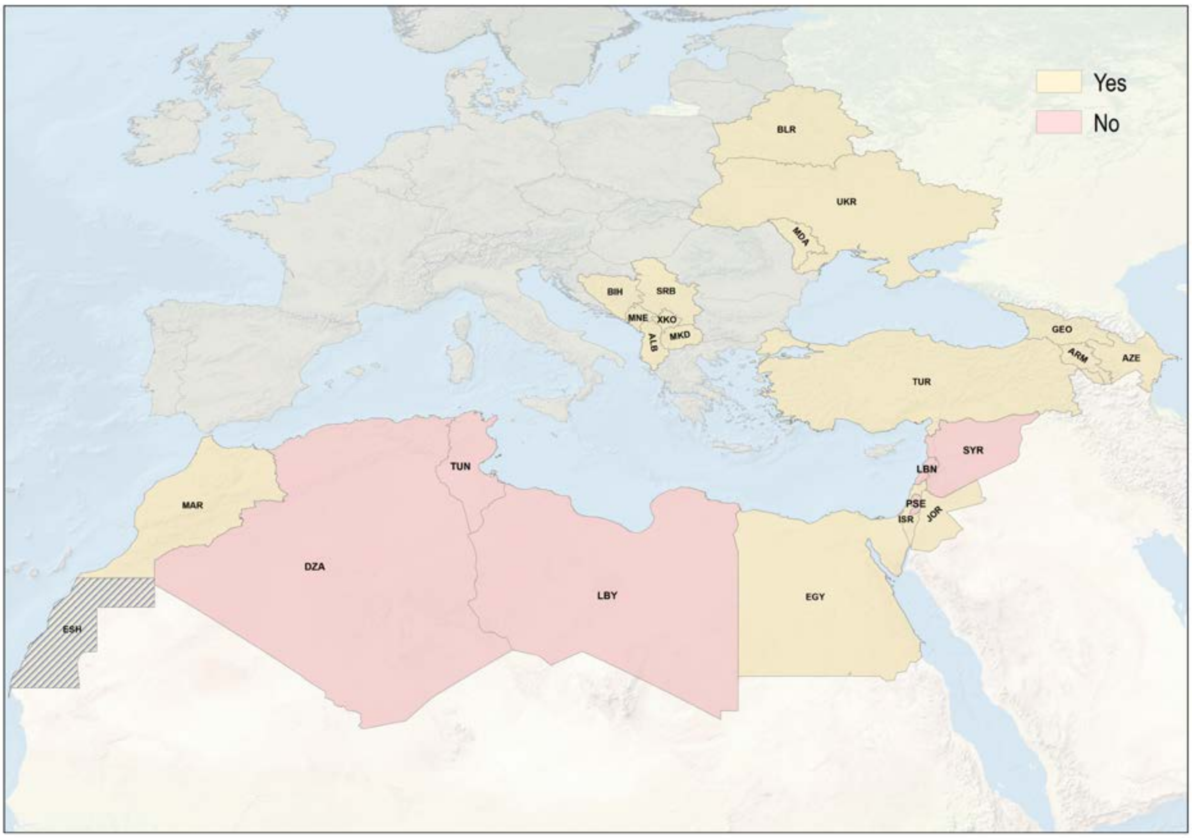

Figure 1 Map of the Eastern and Southern Neighbourhood countries. The countries in yellow are included in this report, whereas we did not find experts in the countries in red. Western Sahara (shaded) is included as a part of Morocco in this report, as Moroccan data include it, but this is without any prejudice to positions on the status.

There are previous assessments that have looked at flood vulnerability in the past in some of these countries. However, flood monitoring systems and early flood warnings systems have only been a minor part of these assessments, they only cover a limited number of countries, or they are older. Examples of reports include:

- SEE PHase 1 ([5]), which is a regional report, covering Turkey and parts of the Balkans
- reducing the risk of water related disasters ([6]), a report by the Dutch disaster risk team from Morocco.

Previous reports have had different purposes, covered different regions, and are mostly older. The current report attempts to give a consistent and recent overview for all countries. Most of the text was written during 2016, with updates until the report has been finalized.

In this report, the authors have been asked to describe the following:

([5]) Strengthening Multi-Hazard Early Warning Systems and Risk Assessment in the Western Balkans and Turkey: Assessment of Capacities, Gaps and Needs. https://www.wmo.int/pages/prog/drr/projects/SEE/documents/SEEPhase %20I %20- %20FinalReport.pdf

([6]) Dutch Risk Reduction Team: Reducing the risk of water related disasters, DDR-Team Mission Report to Morocco — Souss Massa et Draa River Basin/Guelmim http://www.drrteam-dsswater.nl/wp-content/uploads/2016/02/DRR-report-final-Morocco.pdf

- A short summary of geography, climate and hydrological features of the country;
- an overview of organisations involved in meteorological and hydrological monitoring and forecasting;
- an overview of the meteorological observation network;
- an overview of the hydrological observation network;
- an overview of meteorological and hydrological forecasting, alerts and international cooperation;
- an overview of what the author (usually together with the hydro(met) service) sees as the most necessary steps for improving flood monitoring and early warning systems in the country.

The report consists of three parts. The first one is an overall summary of the situation in all countries. The second part is a summary for each country, together with a list of gaps and needs. The last part, and the largest, consists of the individual country reports.

Note that this report does not assess the existing emergency procedures in case of a flood or flood warning. Even though the suitability of these procedures can affect significantly the response to floods these procedures are usually highly specific and, if available, mostly only in the countries language. Hence, these are beyond the scope of a report which assess 17 different countries.

2 Flooding in the assessed countries

There are large differences between the countries when it comes to the geographical and hydro-meteorological situation. Some countries are large (Egypt, Turkey and Ukraine are all above 600 000 km^2), whereas several are below 30 000 km^2 (Albania, Armenia, Israel, Kosovo ([7])), the former Yugoslav Republic of Macedonia and Montenegro). The population density is relatively similar, with most countries having 43-106 persons/km^2 (lowest in Montenegro), whereas Kosovo and Israel has considerably more (165 and 296, respectively). However, some countries have large areas that are uninhabitable, which means that a larger part of the population is concentrated on a smaller area.

The climate and the geography will to a large degree influence the type of flooding and the consequences of floods. These are highly different between countries, and also within countries. None of the countries can be described as homogeneous or simple to model.

The countries in the Middle East and South of the Mediterranean are characterised by deserts, which will only see small amounts of precipitation per year. However, most of the driest areas can also be hit by the occasional extreme rainfall events causing severe flash floods.

Other countries are more characterised by large mountainous parts, with large precipitation gradients and possibilities for landslides. Some countries are extremely diverse, such as Georgia, which has most of the global climate zones, except for tropics, arid desert and savannas.

The highest annual precipitation in the assessed countries is found in Montenegro (up to 4 600 mm), Albania (up to 3 000 mm), Georgia (up to 2 500 mm) and Turkey (up to 2 500 mm). The highest annual averages for the entire countries are found in Montenegro (1 500 mm), Bosnia and Herzegovina (1 250 mm) and Albania (1 200 mm). The driest regions and the highest temperatures are found in the countries in North-Africa and the Middle East. However, flooding is not just a result of extreme precipitation, but also a result of 'more than normal' precipitation for a region. A combination of snow melt and rain can be a cause of flooding in many of the more mountainous countries.

2.1 Distribution of flood types

The hydrologic situation in the different countries will depend on the climate, the geography and how the population is distributed. Table 1**Error! Reference source not found.**gives an overview of how the experts assessed the frequency and the possible consequences of different flood types in their countries. There are of course always differences in how people assess consequence and frequency qualitatively. Nevertheless, several characteristics can be identified from the table. No consequence is given if a certain type of flooding is not relevant for a country.

Most experts classified flash floods and riverine floods as medium and highly frequent events with medium to severe consequences in most of the assessed countries.

The southern countries are mainly occupied with flash floods, which in some cases can cause damage over larger areas. There have been large and devastating flash floods in Morocco and Jordan of the assessment countries, and in Algeria and Tunisia of the countries that have not been assessed. These floods are characterised by a fast onset and short reaction time. Constructions in flood prone areas and lack of flood protection

(7) References to Kosovo: This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

measures have contributed to the large impact of these floods. Many of the streams are completely dry in parts of the year, then flooding after strong rainfall.

The larger rivers in these countries are considerably less prone to the large and disastrous floods. Many of them include reservoirs for water supply, often with a capacity that is higher than the potential size of floods. This is for example the case for the Nile river (below the High Aswan dam), which has not flooded since the construction finished in 1970, and for the Jordan River. Three countries see riverine floods as not relevant for their country.

The table shows that flash floods can be a problem with medium to severe consequences also in almost all countries. Damaging flash floods have hit Georgia, the former Yugoslav Republic of Macedonia and several other countries during the last years. In addition, these countries also have to deal with the floods on the larger rivers, which in many cases gives better opportunities for early warning and evacuation, but where the damage can cover much larger areas.

The countries in the Eastern Neighbourhood region have more rivers of transboundary nature, where good cooperation is necessary for early warning and evacuation. One of the largest floods of this type the last years occurred in Bosnia and Herzegovina and Serbia in 2014 mainly in the Sava and Drina river basins, with more than 60 casualties and an estimated number of 1.5 million people being affected by the floods. Transnational flooding is expected to have medium to severe consequences for nine of the countries.

Coastal flooding, snow melt flooding and ice jams is less of an issue for many hot countries, and coastal flooding does usually not have severe consequences for any of the assessed countries. On the other hand, erosion is an issue for all countries, with medium to severe consequences for all but one. Groundwater flooding is only relevant for 10 of the countries, and has small consequences for most of the countries.

Table 1 Typical flood types and their typical frequencies and consequences ([1]) in the assessed countries

	Not relevant	Rare events	Medium frequent events	Frequent events	Small consequences	Medium consequences	Severe consequences
Flash floods (0-6 hour duration)	1	1	9	6	1	6	8
Urban flash floods (0-6 hour duration)	0	1	10	6	3	9	4
Riverine floods and inundation (duration days)	3	3	5	6	2	6	5
Coastal flooding	7	3	2	3	2	6	0
Groundwater flooding	7	6	2	2	7	1	1
Snow melt flooding	3	5	4	4	6	4	2
Transnational flooding	4	6	3	3	2	2	7
Erosion	0	3	8	5	2	10	4
Changes of flood path	3	3	4	3	4	3	3
Backwater flooding	3	8	3	2	6	4	3
Ice jams	10	3	1	2	2	2	2

(1) Numbers refer to how many reports classify a certain flood type with a certain frequency and severity, e.g. flash floods are classified as medium frequent in 9 reports, frequent in 6 reports, and the consequences are classified as small, medium and severe in 1, 6 and 8 of the reports, respectively.

2.2 Flood protection measures

We have not scrupulously assessed flood protection measures, as this would involve a rather large technical study, which would be out of scope for this report. In addition, information on structural flood protection is usually considered as sensitive information and thus not available. However, as it is mentioned in some of the reports, a few remarks can be made. Most countries have reservoirs which can affect the flood development. In some countries, these reservoirs are used actively, in other countries, the reservoirs are managed locally, or for other purposes (typically electricity production or irrigation) rather than for flood protection.

Most countries have developed some sort of flood risk maps for some areas, although it is highly different how these are made. In some countries (such as the former Yugoslav Republic of Macedonia), these are based on the most frequently flooded areas in the past. Moldova has, on the other hand, recently carried out hydrological and hydraulic modelling for 12 000 km of rivers, identifying flood risks on 3 400 km of these. In other countries, such as Kosovo, the development of such maps is currently ongoing. Many countries are referring to the EU Flood Directive (EU, 2007) in this work. Flood maps are still missing for many rivers, or are only based on previous floods, such as in the former Yugoslav Republic of Macedonia. The flood risk maps will to some degree be used as a planning tool for future flood protection.

2.3 Climate change

We did not assess to which degree countries are adapting to future changes in flood frequency and magnitude due to climate change, but it is clear that climate change might change the possibility for different types of flooding or frequencies to occur in many of the countries referred to in the study. A recent study by Alfieri et al. (2017) analysed globally the effect under different climate change scenarios on economic damage and population affected. Figure 2 shows the expected changes in affected population and damages for three different temperature scenarios.

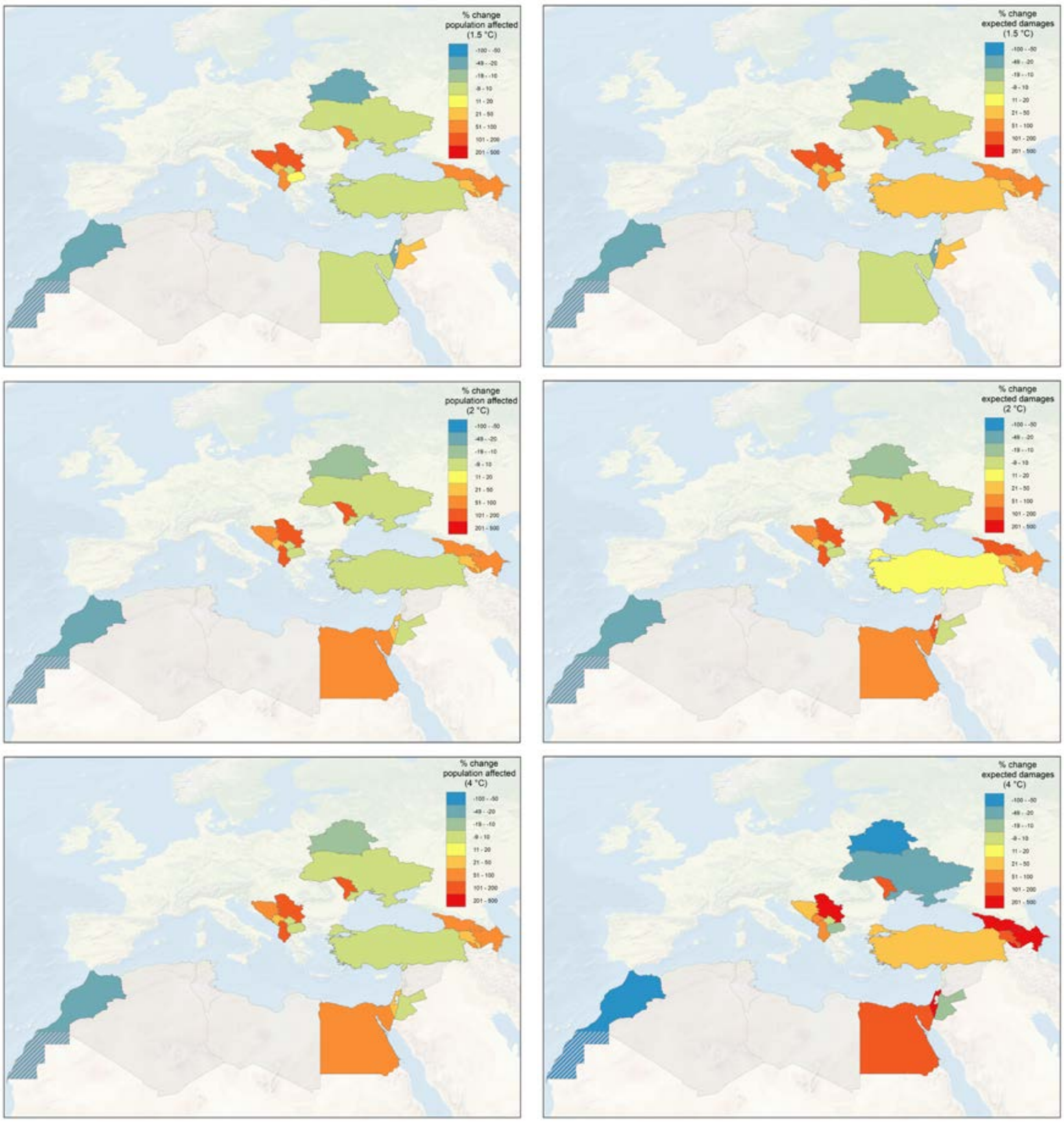

Figure 2 (Left) Average change in population affected and **(Right)** expected damage (right) per country at specific warming levels (based on data from Alfieri et al., 2017).

The median increase in the affected population of the assessment was estimated to 32 %, 47 % and 84 %, under scenarios of temperature increases of 1.5 °C, 2 °C and 4 °C. The median increase of economic damage was estimated to be 30 %, 38 % and 55 % under the same scenarios. The largest increases for the 1.5 °C scenario are seen for Bosnia and Herzegovina and Serbia, whereas Armenia, Azerbaijan, Egypt, Georgia, Israel, Moldova and Serbia are all predicted to see increases above 100 % for the 4 °C scenario. In contrast, the study indicates that Belarus and Morocco will see strong decreases in economic damages and affected population under these climate scenarios.

Despite the rather strong increases, it should be noted that the changes for most countries under the 1.5 °C scenario and some countries under the 4 °C were not significant at the 90 % confidence level, based on the agreement of seven independent climate projections. Globally, the countries of this assessment are not the worst affected, as the increases are lower than the global median for the 2 °C and the 4 °C scenarios.

3 Organisation of hydro-meteorological services

3.1 Organisations

There are significant differences between countries when it comes to the organisation of hydro-meteorological services. Most countries (11) have a single hydro-meteorological service, although some of these countries have regional offices with a high degree of independence, such as Ukraine and Moldova. Belarus has a single hydro-meteorological service, although the civil protection unit (Republican Emergency Management and Response Centre) is more involved in forecasting than in other countries. Egypt, Israel and Morocco have split meteorology and hydrology in different services, usually able to cooperate well. The last three countries have more complicated structures.

The country where the services are most distributed are Bosnia and Herzegovina, where five agencies and institutes are responsible for meteorological monitoring, hydrological monitoring, flood monitoring and early flood warning. There are two hydro-meteorological institutes (the Federal Hydro-meteorological Institute and the Republic Hydro-meteorological Institute of Republika Srpska), together with the Public Institution Vode Srpske, and the agencies for the Sava River Watershed and the Watershed of the Adriatic Sea.

Another country with an apparent complex structure is Jordan, where the Ministry of water and Irrigation is responsible for hydrological monitoring and much meteorological monitoring, whereas also the Jordan Meteorological Department observe meteorological variables. Additionally, the Water authority of Jordan and Jordan Valley authority are responsible for water management. Responsibilities are overlapping, and cooperation is organised through committees and formal agreements.

In Turkey, the responsibilities for hydrological monitoring is formally within The General Directorate of Water Management (SYGM), but is in practice carried out by The General Directorate of State Hydraulics Works (DSI). This is because SYGM does not have the necessary regional presence. In addition, meteorological variables are monitored both by DSI and the Turkish State Meteorological Service (TSMS).

Such structures can work well if the different centres are cooperating well. However, a single organisation is no protection against organisational issues. The State Hydro-meteorological Service (SHS) of Moldova is the sole responsible for hydrological and meteorological monitoring and in flood modelling and early warning. The data handling is split in two centres, which follow geography (North-South) rather than water sheds, something that creates inefficiencies in the daily work. At the moment, the service lacks funding, equipment and qualified staff for a reorganisation of the centres. Attempts to attract funding has not succeeded, as funders are typically focusing on stations, hardware, software and data management.

3.2 Staff

An overview of employees in the services reveals huge differences. However, it should be noted that such numbers might not be completely comparable between countries. In some countries, the employees will include also some people working with hydraulic structures of the rivers. There are also differences in how station observers are counted, some receive full time payment and are regarded as employees, whereas other will only get a small compensation, and are not fully included in the list. A high degree of automation will also reduce the need for staff, even though these stations also need maintenance. The services of some countries also include staff responsible for water works (hydraulic engineering), which is considerably more labour intensive than just observing and modelling.

Despite these differences in the data it is still possible to see some general trends. The hydro-meteorological services in most countries on the Balkans (former Yugoslavia and Albania) appear relatively small (22-200 employees) compared to some of the countries formerly belonging to the Soviet Union (Armenia, Ukraine, Azerbaijan) with 600-1 600 employees. In Turkey, the General Directorate of state Hydraulics Works (DSI) is extremely large (about 24 000 employees), but their activities go very much beyond hydro-meteorology. Formally, the responsibility for monitoring in Turkey lies more with the General Directorate of Water Management, however, this directorate does not have regional presence, and the monitoring is therefore carried out by DSI. A transition of responsibilities is intended, but without a time frame. Also, the African countries in the assessment (Egypt and Morocco) have large services.

A comparison of employees in the services will therefore only be an indication. Also, the degree of automation of stations and their risk for theft and vandalism plays a role here. Countries with a highly automatised observation network and small problems with theft and vandalism can have smaller services than those who still operate a large number of manual stations, or where the automatic stations require more maintenance. The amount of sediment in rivers might also influence rating curves, increasing the need for frequent discharge measurements for updating the curves. The need for permanent observation and modelling in desert areas will of course also be lower than for rivers flowing through regions with denser population.

Figure 3 shows the number of employees in the hydro-meteorological services per 1 000 km^2 (a) and per million inhabitants (b), respectively. Turkey still stands out, but the services of Egypt and Morocco are smaller compared to the size of their territories and population. The service in Montenegro appears larger compared with the population, but the Balkan countries in general still have small hydro-meteorological services.

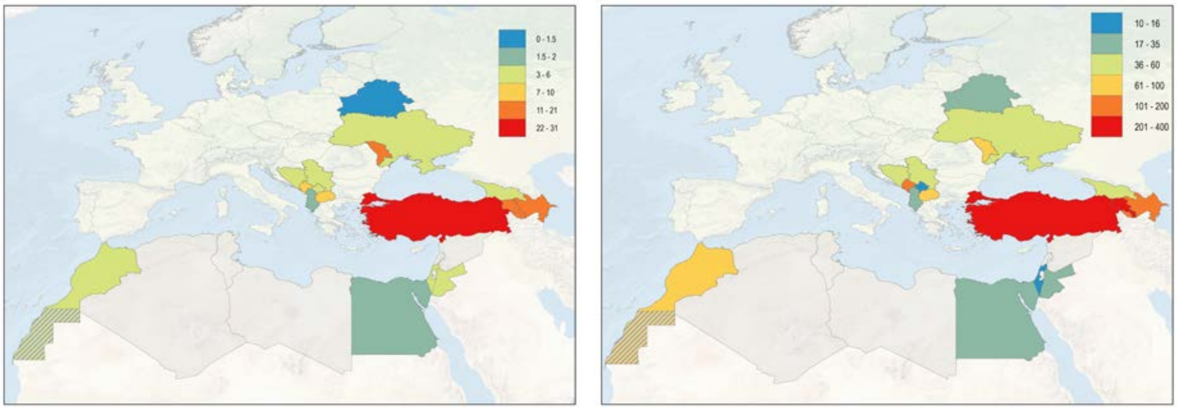

Figure 3 (Left) Number of employees in hydro-meteorological services per 1 000 km^2 **(Right)** Number of employees in hydro-meteorological services per million inhabitants

For most countries, a large share of the staff is working with the observation network. The exact percentage depends somewhat on how observers are counted in the staff numbers (as full- or part-time employees). For the countries where we received numbers, the observation staff accounts for about 50 % of the staff, varying from 20-78 %. This means that the observation network is an extremely labour intensive part of the hydro-meteorological services. On the other hand, a large number of services are lacking staff with a strong background in hydrology, meteorology and IT. This reduces the ability to quality control observations, and to maximise their value for flood forecasting.

The groups working on weather modelling and hydrological/hydraulic modelling is quite small in most countries, from 2-42 in weather modelling and from 1-15 in hydraulic/hydrological modelling. Here we have excluded some countries with considerably higher numbers, as these numbers refers to meteorologists and hydrologists in general (Egypt with 230/185 and Ukraine with 1368/239 for the two fields, respectively). For Morocco and Turkey we don't have comparable numbers. Small numbers means that modelling capacity can be significantly hampered when someone is sick or leaving office.

The percentage of staff working with IT, databases and data transfer is mostly in the range 10-20 percent. These numbers are sensitive to how the staff is reported, but appear to be particularly low in Albania (7 percent) and Armenia (5 percent), whereas it is high in Israel (24 percent) and Kosovo (23 percent). It is even lower in the former Yugoslav Republic of Macedonia (2 percent) and in Ukraine (2 percent), but both of these countries reported the staff slightly different than the majority. We do not have these numbers for Morocco and Turkey.

4 Observation of meteorological variables

Whereas only one country (Republic of Moldova) has completely switched to automatic measurements of meteorological variables, all other countries have a combination of automatic and manual meteorological stations. The measurement frequency ranges from 10 minutes for many automatic stations to yearly for some stations in the desert of Jordan. However, most of the manual stations are observed at least daily, many of them are SYNOP stations with more frequent observations (at least three per day).

Turkey has the highest number of monitoring stations, with 1 580, most of them automatic (1 400). In addition, Israel, Serbia and Ukraine have more than 400 stations. The fewest stations are found in Kosovo (21 manual, 7 automatic), Bosnia and Herzegovina (24 manual, 21 automatic), Moldova (49 automatic) and Armenia (47 manual, 5 automatic). Table 2 gives an overview of the number of stations per country.

All countries now have some automatic stations, but the degree of automation is rather different. Only 6 % of Serbia's 458 stations are automatic. Other countries where there are few automatic stations are Albania (20 %), Armenia (10 %), the former Yugoslav Republic of Macedonia (24 %) and Ukraine (14 %).

Many countries continue to run manual and automatic stations in parallel for long periods after installing automatic systems. There are several reasons why this happens:

- not all variables are measured by the automatic system
- checking the consistency between the measurements
- two or more entities have different stations on overlapping location.

In table 2, such stations are mainly reported as automatic, to give an indication of the percentage of automatic stations. The total number of stations with manual observations can therefore be higher, including also some of the locations with automatic stations.

For flood observation and forecasting, the transfer of observations to the hydrological office is more important than whether the stations are automatic or manual. Some automatic stations are also telemetric, i.e. the observations are automatically transferred as well. But for other automatic stations and for manual stations, the transfer is mainly done in a manual way. Many of them use near-real-time methods like phone (SMS), email, or telefax, but for many stations the observations are only transferred by mail, in some cases only on a monthly basis. However, for many of these stations, the main interest is in climatology, whereas more frequent updates can be requested if a flood situation is expected. The monthly transfer is for example quite typical for several of the countries in the Balkans.

It should also be mentioned that many countries have a combination of stations and posts. The stations usually measure a large number of meteorological variables, whereas the posts are often limited to precipitation and temperature. For meteorological forecasting, it is useful to measure a range of variables, whereas precipitation measurements is the most important variable for flood forecasting.

Table 2 Overview of the meteorological network

Country	Manual	Automatic	Data transfer	Radar(s)
Albania	120	30	Immediately — monthly	1
Armenia	47	5	Immediately	0
Azerbaijan	87	60	Daily	4([1])
Belarus	78	36	Daily	3([1])
Bosnia and Herzegovina	24	21	Daily	0
Egypt	52	100	Immediate — daily	0
Georgia	12	66	Immediate	1
Israel	300	120	Immediate — monthly	2
Jordan	119	35	Daily — yearly	0
Kosovo	20	7	Immediate — daily	0
The former Yugoslav Republic of Macedonia	103	33	Immediate — monthly	2([1])
Moldova	0	49	Immediate	1
Montenegro	29	15	Immediate — monthly	0
Morocco	200	430	Immediate — monthly	7([1])
Serbia	430	28	Immediate	15
Turkey	180	1400	Immediate	16
Ukraine	267	45	Immediate	5

([1]) These radars are old and/or there are problems with maintenance.

Figure 4 shows the total number of stations in each country, per 1 000 km^2. Compared to the area, the absolutely highest station density is found in Israel. Also some of the Balkan countries, except for Bosnia and Herzegovina, have a high spatial density of stations. The lowest spatial densities of stations are found in Egypt, Bosnia and Herzegovina, and in Ukraine.

A general recommendation from the World Meteorological Organisation (WMO 2008) is by some translated to having 2 stations per 1 000 km^2 for mixed terrain. For different regions, the recommendations are:

1. Coastal zones: 1.1 stations/1 000 km^2
2. Interior plains and hilly/undulating: 1.7 stations/1 000 km^2
3. Mountainous regions: 4 stations/1 000 km^2
4. Polar/arid: 0.1 stations/1 000 km^2

Hence, it makes sense that dry countries (Egypt, Jordan and Morocco) have low station densities, whereas hilly and mountainous countries on Balkan and in the Caucasian mountains have higher densities. We can see that most countries fulfil these thresholds. However, Bosnia and Herzegovina and Ukraine have rather few stations, and most of the countries in the Caucasus mountains (Armenia, Azerbaijan, Georgia) have relatively low coverage, according to the WMO recommendations.

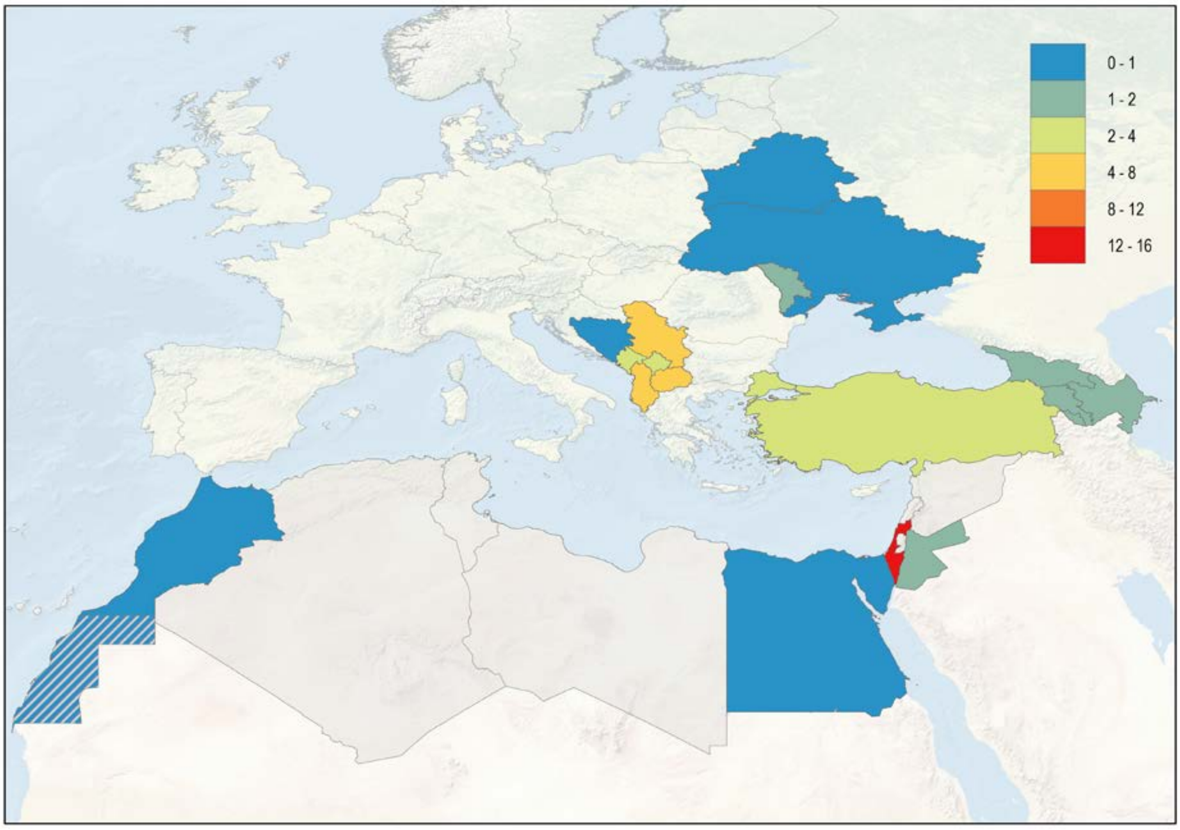

Figure 4 The number of meteorological stations per 1 000 km^2

Many countries have also installed radars to help with detection of precipitation patterns. Turkey and Serbia have 16 and 15, respectively, Morocco 7, Ukraine 5 and Azerbaijan 4. The other countries have from 0 to 2 radars. The necessity for several radars depends on the type of radar and on the size of the country. As an example, 13 of the 15 radars in Serbia are regarded as local. Some countries have old radars with urgent need of maintenance and upgrading. Some of the radars are mainly used for hail detection.

Most countries have digitised their old observations for most of the history, but some work is still remaining in some countries. Many countries have long records, from 50-100 years for many stations. There are also many countries which had denser networks in the past. This is particularly the case for former Yugoslav countries, where the networks have been reduced partly as an aftermath of the wars in the region, and partly because of less resources in the hydro-meteorological offices.

Most countries have standards for quality control. However, there are some countries where the quality controls suffer by a lack of staff (such as in Kosovo and the former Yugoslav Republic of Macedonia).

5 Observation of hydrological variables

The size, density and degree of automation of the hydrological measurement network is for most countries similar to the meteorological measurement network. The largest networks are found in Ukraine (435 stations), Turkey (910 stations), Serbia (275 stations) and Morocco (265 stations). The lowest number of hydrologic measurement stations are found in Armenia (44), Egypt (40), Kosovo (31) and Moldova (48). The largest degree of automation is found in Turkey and Israel (all stations are automatic), while also Bosnia and Herzegovina, Egypt, Georgia, Moldova, Montenegro and Morocco have automatic stations on a majority of their observation locations. Azerbaijan does not have any automatic stations, Armenia, Belarus, Kosovo and The former Yugoslav Republic of Macedonia all have 10 automatic stations or fewer.

Also for the hydrologic networks, the time between observation and transfer of the measurements to the central office is of importance. Data from automatic stations will mostly be transferred immediately, or in the worst cases, daily, whereas data from manual stations is transferred less frequent, sometimes on a monthly basis. The measurements are taken more or less continuously for most automatic stations (down to every 10 minutes), whereas manual stations record with lower frequency, from every three hour to daily.

Whereas some hydrological stations are only measuring water level, the hydrological services will for most stations also estimate discharge, either from direct measurements, or from rating curves. The necessity to update these curves for different water levels will depend on the rivers and the measurement locations. If much sediment is deposited, more frequent updates are necessary. The target is often at least 6-12 times measurements per year, but this is labour intensive work, and again a task which suffers in staff limited services. Kosovo measured from zero to a few times per year in the past, but this has now increased to 12 times per year for some of the main stations, and they plan to measure more other key stations more frequently in the near future. The former Yugoslav Republic of Macedonia have 2-6 measurements per year. From Albania, it was reported that some of the rating curves have not been updated since 2008. They have now acquired new measurement devices and the staff has been trained to use these, but the discharge measurements are still more of a sporadic than routine operation, due to limitations of the staff and financial support.

The situation for quality controls are similar for hydrological observations to the situation for meteorological observations. Most countries have standards, but the operative control in some countries suffer by a lack of staff (such as in Kosovo and the former Yugoslav Republic of Macedonia). This issue is probably of more importance for hydrological variables than for meteorological variables. Most countries have digitised their historical records, but some are still missing.

Table 3 gives an overview of the hydrological networks for each country. Figure 5 shows the number of hydrological stations in each country per 1 000 km^2. Compared to the area, the highest numbers of stations are found in Israel, with high density also in Albania, Armenia and Serbia. Egypt also here has the lowest density of stations. Several other countries (Azerbaijan, Georgia, Jordan, Morocco and Ukraine) have less than one station per 1 000 km^2.

Following the similar station recommendations as for the meteorological network, this might indicate that the density is too low for the countries in Caucasus, Ukraine, and maybe also Moldova and Montenegro.

Table 3 Overview of the hydrological network

Country	Manual	Automatic	Hydrological data transfer
Albania	85	20	2 hours — monthly
Armenia	91	4	Daily
Azerbaijan	101	0	Daily — monthly
Belarus	92	7	Daily
Bosnia and Herzegovina	15	118	Daily
Egypt	10	30	Immediate — daily
Georgia	18	42	Immediate
Israel	0	130	Immediate
Jordan	31	20	Immediate — monthly
Kosovo	21	7	Immediate — daily
The former Yugoslav Republic of Macedonia	65	10	Immediate — daily
Moldova	17	31	Immediate — monthly
Montenegro	3	24	Daily — monthly
Morocco	115	150	Immediate
Serbia	180	95	Immediate
Turkey	0	910	Immediate
Ukraine	372	63	Immediate

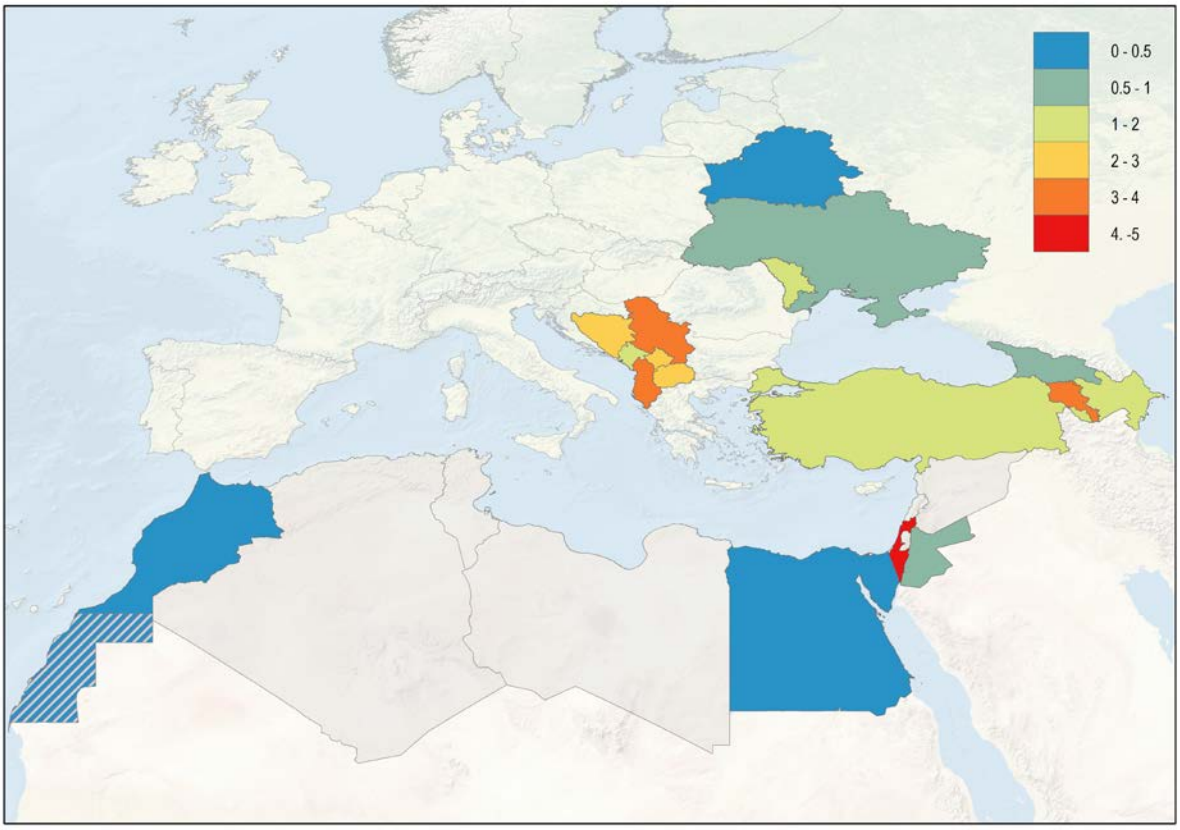

Figure 5 The number of hydrological stations per 1 000 km^2

In most countries only the hydro-meteorological services are allowed to monitor the water levels. In countries where this is also done by private stakeholders, the hydro-meteorological services should normally have access to the data, but this is not always the case. An example is the former Yugoslav Republic of Macedonia, where negotiations with private owners are currently taking place, but the service does not have the capacity for collecting and checking external data.

6 Forecasting, modelling and satellite monitoring

6.1 Weather forecasts

All countries have a meteorological service, which also issues meteorological forecasts. However, whereas the forecasts in some countries are mainly based on analyses of charts from the large scale forecasts from the European Centre for Medium Range Weather Forecasts (ECMWF), The National Centres for Environmental Prediction (NCEP), The German Weather Service (DWD), The United Kingdom Met office and others, other countries have their own numerical weather prediction models, using the large scale models as boundary/initial conditions. The local models are most often a version of the Weather Research and Forecasting (WRF) Model, whereas some countries also have a local implementation of the model from the Consortium for Small-scale Modelling (COSMO).

In countries like Azerbaijan and Moldova, the forecasting is based on analyses of large scale models, radar information and observations, and result in a bulletin with different forecasts (24 hours, 2 days, and 2-7 days with different detail level). Both Egypt and Israel are running their own COSMO and WRF implementations. Most countries with their own forecasting service are running WRF, including Bosnia and Herzegovina, The former Yugoslav Republic of Macedonia, Montenegro, Serbia, Turkey and Ukraine. Armenia and Moldova have ongoing projects for implementing a national weather forecasting model.

Table 4 shows what kind of meteorological forecasts the different countries have available. There are 10 countries with their own numerical forecasting models (National forecasting). Two of the countries are members of ECMWF, whereas three more are cooperating states. Many more countries receive predictions from ECMWF, either the numerical output or charts. Also model output from The Global Forecast System (GFS)/NCEP is quite common, whereas fewer countries receive output from some of the larger meteorological services in France, UK, Germany and Russia.

Table 4 Weather forecasting in different countries

	Member ECMWF [1]	National NWP [2]	ECMWF	COSMO/ ICON	GFS/ NCEP	DWD	UKMO	Local COSMO [5]	WRF	Aladin/ Arpege/ Arome	Other models
Albania			I[3]	I	I				X		
Armenia			I		I	I	I		R[6]		
Azerbaijan			X[4]	I					I	I	ALARO [7]
Belarus				I	X		I				
Bosnia and Herzegovina		X		X	X				X	X	
Egypt		X	X	X			X	X	X		WAFS [8]
Georgia		X	X		X			X	X	X	
Israel	C	X	X		X			X	X		
Jordan			X	I		I	I			X	NCAR [9]
Kosovo			I			I					
The former Yugoslav Republic of Macedonia	C	X	X						X		
Moldova			X		X	X	X		R	X	NOGAPS [10], JMA [11], MS Canada, USAFE [12], NCAR
Montenegro	C	X	X		X				X		
Morocco		X	X							X	ALBACHIR [13]
Serbia	X	X	X		X	X			X		
Turkey	X	X	X						X	X	ALARO
Ukraine		X			X	X			X		KNMI [14]

(1) X means member, C means cooperating state

(2) Which countries have their own numerical weather prediction

(3) I — the country receives images (charts) from the large scale forecasters

(4) X — the country receives numerical forecasts from the large scale forecasters

(5) The country is running a local implementation of COSMO

(6) R — the country is currently implementing WRF

(7) Modified Aladdin from Belgium Royal Meteorological Institute

(8) World Area Forecast System from ICAO

(9) National Centre for Atmospheric Research

(10) US Navy Operational Global Atmospheric Prediction System

(11) Japan Meteorological Agency

(12) US Air Forces in Europe

(13) Maroc Meteo, based on Aladin

(14) Royal Dutch Meteorological Institute

6.2 Rainfall-runoff models

The variability between countries is larger when it comes to the ability to do rainfall-runoff modelling for flood forecasting and flood warning. The majority of the countries do not have any such models implemented, or they only have it for one or two watersheds. Instead, the forecasting is based on expert analysis, based on meteorological forecasts and the last hydrological observations. Some countries have systems to help them in the forecasting, such as Albania using the Dewetra system (Pagliara et al., 2011), to help integrating all relevant data for risk management.

Azerbaijan, Jordan, Kosovo, the former Yugoslav Republic of Macedonia, Moldova and Morocco do not have operational flood forecasting models. Most other countries have models that needs either upgrading/improvements, or they need to be extended to more basins. Bosnia and Herzegovina and Egypt have rainfall-runoff models, but the first only have daily time steps, and the one from Egypt is not regarded as suitable for flood forecasting. Albania and Georgia have models under development.

There are some international projects aiming at better flood forecasting across country borders. Two of these are on Balkan, for the Sava basin and for the Drin basin.

One example is the project ‘Climate change adaptation in the western Balkans’, managed by GIZ and funded by the German Federal Ministry for Economic Cooperation and Development (BMZ). The project focuses on the Drin river, implementing a flood forecasting model for the basin — in the former Yugoslav Republic of Macedonia, Albania, Montenegro and Kosovo. The hydrological model used is Panta RHei (Förster, Gelleszun, and Meon 2012).

The project on the Sava River aims at an improved flood forecasting and warning system (Sava FFWS), mainly integrating existing models, in addition to setting up models for new sub basins. This system will also simplify scenario modelling, where forecasters can modify parameters and or the forecasted input variables.

The types of available models are rather different between the different countries. Some models are rather simple statistical models, other include simple and more sophisticated distributed hydrological models and hydraulic models.

The first group includes models that can barely be referred to as rainfall-runoff models, such as corresponding discharge (empirical dependence between upstream and downstream discharge) and multiple linear correlation, using only upstream measurements. Still these methods can provide useful information for some watersheds, particularly for locations downstream. Such methods are for example used in Serbia.

More complex rainfall runoff models in use include the HBV model (implemented in Bosnia and Herzegovina and Serbia), HEC-RAS ([8]) and HEC-HMS ([9]), implemented in Bosnia and Herzegovina and in Israel, and partly in Kosovo. Additionally, there are projects to start using these models or Mike ([10]) in Albania, Bosnia and Herzegovina and Georgia.

6.3 Flood warnings and alerts

There are differences between the countries in who is responsible for issuing hydrological alerts. The hydrological or hydro-meteorological office is in most cases responsible for identification of a critical situation, in many countries another entity (civil protection, meteorological service, ministry of emergency or similar) has the responsibility of issuing the public warning. Two of the reasons for this distribution of responsibilities are:

— all public warnings (for all types of disasters) are issued by the same entity

([8]) http://www.hec.usace.army.mil/software/hec-ras/
([9]) http://www.hec.usace.army.mil/software/hec-hms/
([10]) https://www.mikepoweredbydhi.com/products/mike-she

— the service does not have a proper information service, and questions/feedback on the warnings are better handled by another entity.

Civil protection and other institutions for emergency management (ministries, crisis management centres) are responsible for issuing the alerts in countries like Albania, Armenia, Belarus, Georgia, Israel and the former Yugoslav Republic of Macedonia. The Hydrological office or the hydro-meteorological office is responsible in countries like Azerbaijan, Kosovo, Moldova, Morocco, Serbia and Ukraine. In countries like Egypt and Turkey, the alerts are disseminated by the meteorological office.

6.4 Satellite monitoring of disasters

The fewest countries have access to satellite images during an emergency situation. Exceptions are Turkey, which have access to images from RASAT, a satellite with disaster monitoring as one of the main missions. However, the country has still not used the images during a disaster. Egypt launched the satellites EgyptSat-1 and 2 for disaster monitoring in 2007 and 2014, but none of them are still operational. There is an agreement with Russia though, for images from Resurs and Kanopus. Otherwise, a few countries (such as Serbia) has experience in receiving images from the Copernicus Emergency Management Service ([11]) during disasters, but in most countries, there is a lack of knowledge about this possibility, at least in the hydro-meteorological services.

6.5 International cooperation

Flooding is quite often a transboundary issue, and all countries have some sort of cooperation with the neighbours. However, it is quite different how formalised the cooperation is.

First, all of the assessed countries that are covered by the current extent of the European Flood Awareness System (EFAS), are now also partners of EFAS (except for Turkey, where only the western part of the Marmara region is covered). EFAS is a partner based service under the umbrella of Copernicus Emergency Management Service, monitoring and forecasting flood events across Europe. In addition, of the countries which are completely or partly covered by the extended domain of EFAS (available soon), Israel is already a partner. This system offers probabilistic 1-10 day flood forecasts for all rivers above 2 000 km^2 in addition to flash flood forecasts and a range of related products (such as observed and forecast precipitation, remotely sensed and estimated soil moisture content and snow depth).

Many countries are also covered by the South Eastern Europe and the Black Sea and Middle East Flash Flood Guidance Systems (SEEFFGS and BSMEFFGS) from WMO. This system is (as described in the name) mainly focusing on flash floods. The system will estimate how much precipitation is necessary to reach bank full flow, which then can be compared with the predicted precipitation. Both of these regional systems are hosted by Turkey.

The above mentioned Sava River Flood Forecasting and Warning System covers many countries, and will help integrating a range of different forecasts in a single application. This could also include external forecasts, such as EFAS and SEEFFGS.

There are also other EU driven projects that bring countries together:

1. IPA FLOODS — has been developed in order to support the approximation to the EU Floods directive in Western Balkans counties and Turkey. It is a Programme for Prevention, Preparedness and Response to Floods ([12]).

([11]) http://emergency.copernicus.eu/
([12]) http://ipafloods.ipacivilprotection.eu/

2. IPA DRAM — In the same framework, the Programme for Disaster Risk Assessment and Mapping (IPA DRAM) contributes to enhance the capabilities of the partner countries to strengthen disaster risk management ([13]).
3. Projects covering the Danube basin under the EU Strategy for the Danube River and ICPDR (International Commission for the Danube River) provided means of formalised cooperation for Serbia, Bosnia and Herzegovina, Montenegro, Moldova and Ukraine. As an example, the FLOODRISK project involved a joint mapping exercise for flood hazard and flood risk and data harmonisation in the transnational Danube river floodplains ([14]).

In the Middle East, the Jordan River basin commission has Jordan, Syria, Lebanon, Israel and Palestine as members. However, as the flood risk along the Jordan River is very low, due to large reservoirs, the commission is more active with river rehabilitation and protection against contamination.

Almost all countries have cooperation with the neighbours, either formal or informal. However, there are some exceptions. Turkey cooperates with Georgia, but has limited to non-existing data exchange with the other countries along the Eastern and Southern border (Syria, Iraq, Iran, Armenia). There is also poor cooperation between Azerbaijan and Armenia.

([13]) http://www.ipadram.eu/about-the-programme/
([14]) http://www.danube-floodrisk.eu/

7 Reported gaps and needs

The experts were all asked to describe the most important needs for improved capacity for flood monitoring and early flood warning, and to prioritise the needs. For many countries, there were many gaps that all got a high priority. Although this could be seen as a lack of prioritisation, it is also an indication that there are many issues that need to be solved to improve the capacity.

7.1 Meteorology

Some countries are mostly satisfied with their current number of meteorological stations, but the majority would like to get a considerable number of new meteorological stations. Jordan (with ongoing upgrades) and Moldova are the countries which have more or less sufficient number of stations. In many other countries, the main emphasis is on replacing manual stations with automatic stations, and in some of them, to increase the number of variables measured. Many mountainous countries report a need to extend their network in the higher altitudes.

Georgia and Ukraine are the countries where the experts see the highest need for new stations, about 200 in each country, whereas 120-140 stations were recommended for Bosnia and Herzegovina (increasing from today's 45). The reasoning is that Georgia has a bad coverage in the mountains, whereas the other two countries currently have a relatively low station density (see Figure 4).

For many countries, the suggested number of stations will mainly be a replacement of existing manual stations with automatic stations. This is for example the case for Albania (currently, 120 manual and 30 automatic stations), Armenia (47 manual and 5 automatic), the former Yugoslav Republic of Macedonia (127 manual and 16 automatic) and Serbia (430 manual, 28 automatic). Some of these would also like to add new locations, particularly in higher altitudes, such as the former Yugoslav Republic of Macedonia (20 stations) and Serbia (40-50 stations). Turkey has the largest meteorological network, with a high degree of automation, but due to the size of the country and the climatological diversities, also this report suggests an increase of about 50 locations, to particularly cover mountainous areas of the river basins along the Black Sea and Mediterranean.

Whereas many countries have good working radar systems, other countries are either still completely missing such systems, or they are relying on old systems which are not suitable for now — or forecasting of extreme events. Armenia, Bosnia and Herzegovina, Egypt, Jordan Kosovo and Montenegro are completely missing radars. Azerbaijan, the former Yugoslav Republic of Macedonia and Morocco have old systems which are not properly maintained or need maintenance.

7.2 Hydrology

The situation regarding what the experts suggest as improvements for the hydrological network is similar to the situation for the meteorological network. Some experts recommend quite a large number of new stations in their reports, such as for Georgia (100 stations) and Ukraine (100 stations). In these and other countries, the need for completely new stations are usually some stations in mountainous regions, to have better observations for the upstream parts of catchments.

Most services also want to replace manual stations with automatic stations which transfer observations automatically. This will, to some degree, reduce the necessity for permanent staff, but the picture is not as obvious as expected. Often these systems will require more maintenance from technical staff, which can also be a limitation in some services. This is for example mentioned in the report from Albania, where a complete change to automatic stations is not seen as feasible because of their limited technical staff. Manual observers are cheap in many countries (only given a small compensation), whereas technical staff is more expensive and limited, even if fewer persons can cover more stations. They also mention that the hydrological network is more affected by vandalism and debris from river water than the meteorological network, increasing the need for maintenance. They recently got a set of automatic stations financed from the World Bank, and half of these were damaged within a couple of years.

A last issue regarding the suggested number of stations, is that some countries have operative and observational networks (both for hydrology and meteorology). Whereas the number of stations might be relatively high, many of them are more for the long term water resources, and observations are not transferred before the end of the month. Hence, upgrading observational stations to operative stations, with increased reporting frequency, would also improve flood monitoring capacity. Azerbaijan is a country with 101 stations, but only 42 are operative, sending measured water level at least twice a day to the forecast bureau.

It is relatively easy to measure water level, but more challenging to estimate discharge from these. Together with automatic measurement stations, there has to be a program for measuring discharge regularly, to keep rating curves up to date. Some countries need more devices for better discharge measurements, particularly during flood situations.

7.3 Data availability

Some countries already have all/some of their meteorological and/or hydrological observations/forecasts available through online services, as numbers, charts, or as maps. This includes countries like Bosnia and Herzegovina, Georgia, Israel and Montenegro. No countries are offering data through OGC-compliant services, with the exception of Web Map Services, which cannot be post-processed.

In other countries, data is available, but not to the public. Armenia has the observations from a couple of stations available, but only through a password protected page. Turkey has limited access to hydrological data from some transboundary rivers. In Ukraine, the data is not available for free usage, the restrictions have both technological and political character.

Some countries still need some of their old data to be digitized. This includes Albania, Armenia, Bosnia and Herzegovina, and several others. Previous projects have largely improved the situation in some countries. As an example, the CARPATCLIM ([15]) project covered 6 countries (including Ukraine and Serbia from the current report), and millions of old records were digitised in the frame of the project, particularly improving the situation in Ukraine.

7.4 Weather forecasts

The countries which don't get numerical weather predictions from the regional forecasters see this as a quite urgent need. Albania would like to be member of ECMWF. As a second step, most countries without capacity for national NWP would also like to introduce this.

7.5 Rainfall-runoff models

Introducing a rainfall-runoff model for operational flood forecasting is a relatively large effort, still somewhat depending on the type of model and how it is supposed to be used. Many countries have hydrologists who can give relatively good flood warnings, based on observations and meteorological forecasts, combined with their experience of the basin

([15]) http://www.carpatclim-eu.org/pages/home response. Particularly for smaller basins, it is not straightforward to translate this knowledge into a numerical forecasting model, integrating all necessary input data. When focusing on the smaller catchments, input data can often be wrong.

There is in general a long way from feasibility studies and calibration of a model to operational flood forecasting based on the same model. An example is the flood warning system that is currently being set up for the Drin basin in Albania, Kosovo, the former Yugoslav Republic of Macedonia and Montenegro. This project has been running for several years, managed by GIZ and funded by the German Federal Ministry for Economic Cooperation and Development. A calibration of the hydrological model (Panta Rhei) was finished long time ago. However, there is still work to be done before the system will be running operationally. Some of this is technical developments, such as simulation of cascade operations, lake models and in the future also a hydro-dynamic model of the risk areas, in addition to setting up the entire work flow with real-time data and weather forecasts in addition to the historical data. However, the main effort will be on user training and capacity building.

Some countries do have rainfall-runoff models, but running with a lower temporal resolution (typically daily) than what is needed for flood forecasting on small to medium sized rivers. This is for example the case for several models being used operationally in Bosnia and Herzegovina.

Staff and staff skills are among the most important challenges in setting up flood forecasting models, something which is also mentioned under the priorities. Most of the countries without models running will need both more staff and more training of the staff to be able to implement or run models.

7.6 Staff

As mentioned above, staff limitations is one of the challenges regarding implementation of operational flood forecasting models, but also regarding the current operational work of the services. Many countries report challenges regarding staff. This is first of all regarding size of the staff, where the group involved in flood monitoring and flood warning is often limited to a few persons. However, also in larger services, almost all request for more training of the staff. The staff numbers might be sufficient, but their knowledge is not corresponding to the current needs of the services.

The necessary training includes everything from basic hydrology to modelling, GIS and IT-knowledge, for different groups of staff. There is also a need for more technical knowledge in some of the countries, about how to maintain the more advanced measuring networks with automatic stations and telemetric data transfer, and how to operate and maintain radars.

Further challenges regarding training is that students in some countries (mentioned for Armenia) will not be able to find a suitable education in their country, the necessary knowledge is not part of the curriculum.

Whereas new staff is needed and wanted in the institutions, there are both administrational and funding challenges for many countries. The Hydrological Department in the former Yugoslav Republic of Macedonia has only employed one person during the last 20 years, which means that the department has been reduced from 35 to 14 people through retirement.

One issue which is not directly related to the staff itself, but which can highly impact the working conditions of the staff, is how the service is organised. Some of the reports point out strong needs for reorganisation. This is the case for Moldova, where two Hydrological Centres are responsible for their respective parts of the country, but where the division between responsibilities was done without considering data handling efficiency.

7.7 International cooperation

Many countries have good cooperation with neighbouring countries, but still report that this can be further improved. In the Albanian report, it is mentioned that standardisation is necessary, both domestically and with neighbouring countries. This includes both how to identify and code national water bodies, and how to standardize event probabilities at the river basin scale for transboundary rivers. Also the Egyptian report emphasises that the cooperation with neighbouring states is good, but that there is still a need for the systems to exchange data, and for the services to exchange experiences.

Some neighbouring countries have poor cooperation due to conflicts at state level. This is for example the case between Armenia and Azerbaijan, and between Armenia and Turkey. However, hydro-meteorological cooperation can still exist despite ongoing and previous territorial disputes, such as between Ukraine and Russia, and between Georgia and Russia. The countries on both sides are still fulfilling agreements about data exchange and communication during flood situations. And even if cooperation is poor, it is sometimes possible to meet through international projects. One example is the EU funded project Prevention, Preparedness and Response to Manmade and Natural Disasters (PPRD2). The PPRD2 Programme supports international cooperation for the reinforcement of Civil Protection capacities between the European Union, the Mediterranean (PPRD South2) and Eastern Partnership Countries (PPRD East2) under the umbrella of the European Neighbourhood Policy. Here, attempts are being made to improve flood management through strengthening of the interagency cooperation and application of the EU approach in the area of flood management. Further developments and results of these programmes are presented on the Electronic Regional Risk Atlas (ERRA) ([16]) for PPRD East and the PPRD South Risk Atlas for the South ([17]).

The most developed form of cooperation will be when the countries are running joint forecasting models on the transboundary rivers. This is a wish from many countries, but still a challenge for most, as this will be even more complicated than setting up national models, having to merge data from different sources following different standards.

The countries are generally interested in joining international organisations, both for meteorology (ECMWF, for several of the ones that are not currently members) and for hydrology.

7.8 Domestic cooperation

It is reported for most countries that domestic cooperation is good but for some countries, this could be further improved. In Azerbaijan, the cooperation could be better between The Hydrometeorology department and other related organisations, dealing with water issues. A joint data portal would be a first step for better cooperation. More surprisingly, it was reported that there was no cooperation between the meteorological and hydrological offices in Israel until recently. This has now improved, but there is still a challenging transition period where they have to work our procedures for whom is doing what and how to communicate with the users, e.g., the ministry for civil protection and municipalities. Also in Morocco, a team from the Dutch Disaster Risk Reduction facility ([18]) identified better cooperation between the meteorological institute and the hydraulic departments as necessary.

([16]) http://erra.pprd-east.eu/
([17]) http://www.euromedpprdsouth2.eu/en/27-risk-mapping/
([18]) Dutch Risk Reduction Team: Reducing the risk of water related disasters, DDR-Team Mission Report to Morocco — Souss Massa et Draa River Basin/Guelmim http://www.drrteam-dsswater.nl/wp-content/uploads/2016/02/DRR-report-final-Morocco.pdf

The report from the former Yugoslav Republic of Macedonia pointed out that legislation in some countries needs to be modified to protect hydro-meteorological stations from different type of construction on the location or nearby.

7.9 Other gaps

A few of the countries also included other gaps than the ones above, mainly related to infrastructure. In Moldova, there is a need for new building before it is possible to reorganise the centres of the hydro-meteorological service. In the former Yugoslav Republic of Macedonia it is necessary to modernise the Protection and Rescue Directorate (PRD), and there is a need for better cooperation between PRD and the Crisis Management Centre.

7.10 Priorities

The experts were asked to give priorities (1-10) for different improvements towards increased capacity for flood monitoring and early flood warning. Many of the experts gave priority 10 for most of the suggested improvements. This could indicate a lack of prioritisation, but also that many steps are necessary in most of the countries. Most countries have hydrological and meteorological stations as the main priority, either additional stations, or upgrade from manual to automatic stations. After this, training receives the highest priority from many countries. A detailed list of the priorities can be found in the country reports in the appendix.

8 Recommendations

This section will summarize recommendations based on the interpretation of the reports, and the long-term experience of the JRC working with some of the relevant hydrological and meteorological services in these and similar countries.

First some general recommendations:

- When funding, strong collaboration with all different involved authorities is needed. This should be fostered by including them in new developments at the earliest possible stage.
- International cooperation is important and should be further fostered, particularly in situations with staff limitations and financial reductions.
- Projects for new developments/improvements should always have a 'test operational' phase, which includes the initial operational support and which should ensure that there is at least some long-term sustainability of the new developments/improvements after the project ends.
- The countries should be encouraged to develop medium to long term plans for their monitoring and early flood warning capacities, which then should be followed to a large degree by funding organisations. Development of such a plan could be a project in itself, which might require funding and support from supporting organisations and countries.

8.1 Monitoring networks

A well working spatially distributed monitoring network is the core of flood observations and the possibility to give early warning. Operation and maintenance of the network will in many countries include more than 50 % off the staff employed in the hydro-meteorological sector, and is responsible for a substantial part of the budget of the services.

It is therefore natural that many countries are interested in extending their network, and that funding organisations are frequently contributing with new stations. However, the last years' experience shows that many network extensions end up without an improvement in the operative network. The keyword is maintenance, which is usually not a part of the funding. Many services are staff-limited, and new stations will not solve this problem. Therefore, new stations have to have a strong emphasis on low maintenance costs. This includes costs for repairing the station, regular checks etc. Funders should also focus on protection of the stations against natural and anthropogenic damage.

The following principles should be followed when installing new monitoring stations:

- ensure that stations will be maintained, whether this is a part of the funding, or a more formal commitment from the receiving service;
- new stations should be as compatible with the existing network as possible, to avoid biases and maintenance inefficiencies;
- low maintenance costs (repairs, data transfer, regular checks), both financially and staff-wise;
- well protected stations;
- rather than increasing network density (except for a few countries), the focus should be on automatic devices with telemetric transfer;
- rating curves must be updated frequently, and devices and support for doing this should be an important part of funding of hydrological networks;

- radar stations are necessary in many countries, especially in the countries where flash floods have the highest risks. Radar data could and should be exchanged across borders. It should, however, be noted that precipitation radars require a relatively high level of expertise and a minimum of IT infrastructure to manage the high frequency data volumes and the interpretation and maintenance of the radar.

8.2 Hydrological and meteorological forecasting

Many countries still rely on interpretation of the large-scale NWP models for meteorological forecasting, often based on charts only. Implementation of more local models (typically WRF) would be useful for many countries. Local meteorological forecasting could take place in regional centres, not necessarily in each country. As such, the South-East European Consortium for Operational Weather Prediction (SEECOP) ([19]) is of interest, and is maybe an example to follow. The project aims at setting up numerical weather prediction models for the participating countries, i.e. Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro and Serbia.

The same is the case for hydrological forecasting, where transboundary rivers should ideally be modelled by a single model. However, there are also more challenges here, as many of the tributaries are smaller and not transboundary. There is also the challenge with the model choice and forecasting consistency, as some countries are running some models for their national rivers, whereas other models might be chosen for the transboundary rivers. Improved cooperation across borders is the keyword here, including standardisation of hydro-meteorological information and exchange of data.

Some general recommendations.

- The same model should be used as much as possible within the same service, to build expertise and experience.
- Neighbouring countries should join efforts for modelling, both for transboundary rivers, but also for watersheds of similar type, such as when a mountain range is the border between the countries.
- Rainfall-runoff models might not be necessary everywhere, simpler models also have good merit for some cases, such as statistical models for larger rivers and rainfall driven indicators for flash floods.
- International, large-scale forecasting systems such as EFAS, that aim at providing added value through probabilistic, medium range forecasts and other relevant products, represent a low-cost option, to further improve flood monitoring and forecasting in the relevant country.

8.3 IT infrastructure and data

Many countries express a need for new computer infrastructure to solve issues regarding data handling and modelling. However, similar to the monitoring networks, maintenance of the IT infrastructure can often not be ensured and hampers the long-term sustainability of the investments in IT infrastructure. Whereas there is a strong need for new capacities here, we would recommend, where suitable, an extended use of cloud services. This could reduce the need for IT hardware installed and maintained on-site, and it would make it easier to scale the services. Also data exchange would be easier with this setup. However, there might be legislative issues in some countries about uploading data to external servers.

([19]) http://seecop.meteo.co.me/documents/SEECOP_Modelling_Concepts_and_Plan_of_Activities.pdf

- Data must be harmonised according to international standards.
- Cloud services must be considered as an option.
- It is still necessary to invest in data rescue (digitalisation of old records) in some countries.

8.4 Training

Training and improving the skills in the services seems to be an essential issue for most of the countries. Recruiting the right skills would be the solution in some cases, but not every country has internal capacity for the right education in colleges or universities. If possible, the services should work with the universities to develop curriculums that would be better suited for their needs. This could also include exchange programs, where staff from the authorities are teaching part time for the universities, funding of traineeship programs for students in the authorities and summer schools for students and employees. Recruiting from abroad is an option, although language might be an issue. Many services have staff limitations, making skill increase through recruitment a slow process. Training of existing staff is therefore necessary for improving the skills. International training programmes would therefore be very useful. These could be offered as stand-alone training, or particularly directed to improvements in their systems.

Much work is needed for development of a training course, whereas less work is needed to repeat the training. If training is planned for a country, as a part of a project, it would be efficient usage of the resources to also include participants from the neighbouring countries, or to repeat the training in the neighbouring countries. By repeating, it is also easier to include those who are not able to travel, for example due to staff presence. Some training can be given through webinars. This is for example the case of training given by EFAS for some of their products.

Language is certainly a barrier when it comes to training as many of the specific training courses are only available in English. Whereas there is always someone in the services with a good command of English, courses in English will only be relevant to a limited group of the staff in many countries. This is particularly the case for older staff in countries in eastern Europe, who might have Russian or another Slavic language as their second language. Training courses must therefore be planned with this barrier in mind, and should be given in different languages, alternatively with translators. When giving courses in one country, staff from countries with similar languages should also be invited.

There is clearly a lack of knowledge about the existence of Copernicus Emergency Management Service — Mapping. Only Turkey reported to have national access to satellite imagery during a disaster, although it has so far not been used during an actual disaster. At the same time, the knowledge of mapping services from Copernicus are close to non-existing in the hydro-meteorological services. Hence, it would be very useful to target them with information about the possibilities. Even if most of these countries will not have the right to make a direct request themselves, they should be better informed about the existence of these products and who they would have to contact.

8.5 Other

Although we did not thoroughly analyse the existence of flood risk maps in the different countries, it is clear that their level of development is very different in different countries. Many of the countries would benefit from a harmonised risk assessment, for example following the EU Flood directive (EU, 2007).

9 Conclusions and key strategic recommendations

We have assessed the capacity for flood monitoring and early flood warning in all (six) enlargement countries, all (seven, including Kosovo) Eastern Neighbourhood countries and four out of the ten Southern Neighbourhood countries. The assessment shows large differences in capacity between countries, and with different challenges. Whereas some countries are technically advanced, have good networks and are relatively well prepared for flooding events, other countries are in the process of rebuilding services and networks.

Most of the countries will partly depend on external funding for improvements to their systems. Although we have not analysed the outcome of previous funding, it is clear that the long term results are not always as positive as expected. This report should therefore help in making better priorities for future funding.

First of all, it is pointless to install new stations without having a realistic maintenance plan. Unfortunately, many funding organisations are currently limited to only fund new infrastructure, increasing the risk of installing stations that will fail after a short period.

Secondly, the staff and their skills is a limitation in being able to handle an increased and more automatised network, and for being able to incorporate new technologies and methodologies. Better university studies and courses for existing staff is necessary. It should also be noted that the size of some services are at a level where departure of core staff could case periods with reduced flood forecasting capabilities.

Below we are giving some of the main challenges for capacity for flood monitoring and early flood warning in the assessed countries, together with recommendations.

Challenge: little coordination between funding bodies and programmes and short term ad hoc solutions.

- Solution: Encourage countries to develop a coherent medium to long term management investment plan and channel the funding according to a plan and not on ad hoc basis. This should ideally be done in collaboration with neighbouring countries.

Challenge: lack of communication between authorities

- Solution: Financing of Community of Practice, steering committees, knowledge centres to ensure that information is exchanged between the services. This would be for information only and thus not ‘step on toes’.

Challenge: lack of expertise in the services

- Solution 1: Foster a strong link between authorities and universities. This could be done, for example, through funding the exchange of lecturers between authorities and universities, funding of traineeship programmes with students going to authorities for internships, or the funding of summer schools with the possibility for staff from the authority to attend.
- Solution 2: explore options to improve skills of existing staff members through trainings, back-to-university courses and webinars. Language barriers should be taken into account as well as the possibility to hold training courses for a various countries together.

Challenge: station network and maintenance

- Solution 1: Standardisation — there should not be different standards from one authority to another, or from one river basin to another within the same country as this would then make exchange and intelligent use of equipment and sharing of data more difficult
- Solution 2: Funding of national programmes for innovation on low cost and low maintenance solutions for equipment

- Solution 3: Foster innovation projects on low cost equipment taking into account latest standards of technology
- Solution 4: Countries with risk of flash floods should install/upgrade rainfall radars and get expertise to operate them. The radars should cover a larger area than the actual region of interest to be able to detect the arrival of potential heavy precipitation systems. Building a network or collaboration with neighbouring countries to provide access or share the relevant radar information is therefore important.

Challenge: modelling

- Solution 1: Streamline transition from hydrological model set up to operational system based on best practices
- Solution 2: Good results can for many watersheds be achieved with simpler models, it is often not necessary to implement highly complex models.
- Solution 3. Transnational operational modelling should be fostered. This is both for meteorological and hydrological modelling. Transboundary modelling will both be beneficial for the forecasts, and also for the general cooperation and information exchange between the services.

Challenge: IT Infrastructure

- Not all infrastructure needs to be hosted by the services, cloud services could be used more frequently.

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List of abbreviations and definitions

BMZ	German Federal Ministry for Economic Cooperation and Development
BSMEFFGS	The Black Sea and Middle East Flash Flood Guidance System
CARPATCLIM	Climate of the Carpathian Region
COSMO	The Consortium for Small-scale Modelling
DDR Team	Dutch Disaster Risk Team
DG ECHO	The Directorate-General for European Civil Protection and Humanitarian Aid Operations
DSI	The General Directorate of State Hydraulics Works
DWD	The German Weather Service
EC	European Commission
ECMWF	European Centre for Medium Range Weather Forecasts
EFAS	European Flood Awareness System
ENI	European Neighbourhood Instrument
ENP	European Neighbourhood Policy
ERRA	Electronic Regional Risk Atlas
EU	European Union
FFWS	Flood forecasting and warning system
GFS	The Global Forecasting System
GIS	Geographical Information Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit Gmbh
HBV	Hydrologiska Byråns Vattenbalansavdeling
HEC HMS	Hydrological Engineering Center — Hydrologic Modeling System
HEC-RAS	Hydrological Engineering Center — River Analysis System
ICON	Icosahedral Nonhydrostatic Model
IPA	Instrument for Pre-accession Assistance
IPA-DRAM	the Programme for Disaster Risk Assessment and Mapping
IT	Information technology
JMA	Japan Meteorological Agency
JRC	European Commissions Joint Research Centre
KNMI	Royal Dutch Meteorological Institute
NCAR	National Centre for Atmospheric Research
NCEP	The National Centres for Environmental Prediction (USA)
NOGAPS	US Navy Operational Global Atmospheric Prediction System
NWP	Numerical Weather Prediction
OGC	Open Geospatial Consortium
PPRD2	Prevention, Preparedness and Response to Manmade and Natural Disasters
PRD	Protection and rescue Directorate (the former Yugoslav Republic of Macedonia)
SEE	South-east Europe
SEECOP	The South-east European Consortium for Operational weather Prediction
SEEFFGS	The South Eastern Europe Flash Flood Guidance System
SHS	The State Hydro-meteorological Service (Moldova)
SNP	Southern Neighbourhood Policy
SYGM	The General Directorate of Water Management
TSMS	Turkish State Meteorological Service
UK	The United Kingdom
UKMO	The UK Meteorological Office
USAFE	US Air Forces in Europe
WAFS	World Area Forecast System
WMO	World Meteorological Organisation
WRF	Weather Research and Forecasting Model

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Annex 1. Summary of country reports

Albania

Albania is a relatively hilly and mountainous country of 29 000 km^2 with a Mediterranean climate. The largest amount of precipitation falls in October-March, as snow in the mountains. The annual averages range from 600 mm in the southeast to 3 000 mm in the Albanian Alps. Most of the runoff generated on the Albanian territory drains to the Albanian coast of Adriatic and Ionian Sea, only a small part through the Danube. Flooding is frequent, and typical for the period November-March. The largest basin is the Drin-Buna basin with 20 000 km^2.

Three institutions are monitoring meteorological variables in Albania. The Institute of Geosciences, Energy, Water and Environment (IGEWE) at the Polytechnic University of Tirana has the majority of the meteorological stations, and is the only one monitoring runoff. IGEWE is also responsible for flood forecasting. The organisation seems understaffed, with 8 meteorologists and 12 hydrologists for observation, data management, operational service, and modelling. Other stations are operated by the Military Meteorological Service (9 stations for military air force purposes) and the National Air Traffic Agency (1 station at Tirana airport).

Meteorological variables are recorded on 150 locations in Albania. Manual observations are carried out on all locations, 30 of them are additionally equipped with automatic meteorological stations, and 16 have automatic rain gauges. The automatic rain gauges are sensors included in the hydrological stations installed by the World Bank, but these are not according to WMO standards, and can be seen as unreliable. Data has been digitized from 2001. The automatic stations are transmitting every two hours, the manual stations monthly. Gridded weather products are available from Cosmo and ECMWF.

There are currently 105 stations in the hydrological network, all have manual measurements, 20 are also equipped with automatic stations. The automatic stations are transmitting every two hours, the manual stations monthly. Old records have been digitized from 2001.

The quality control of meteorological and hydrological variables is limited. Some procedures are automated, but IGEWE does not have the capacity for manual QC. Rating curves have not been updated since 2008. Observations from networks from different projects are currently stored in different databases, but GIZ has offered support for a joint database.

Forecasting is mainly done by experts by analysing meteorological forecasts and hydro-meteorological observations through the systems Flood-PROOFS (small and medium-sized catchments), and DEWETRA (national scale). No rainfall-runoff models are currently operational, although the Panta Rhei model, implemented by the University of Braunschweig, Germany, is planned to become operational soon for the Drina-basin in all countries. IGEWE prepares bulletins for natural hazards, whereas the General Directorate of Civil Protection (GDCP) gives alerts to the public.

Albania is a partner of EFAS, and is also covered by the South East Flash Flood Guidance System (SEEFFG), offered by WMO.

The number of meteorological and hydrological stations is regarded as sufficient, but more automatic stations with telemetric data transfer is necessary. Staff limitations is an issue affecting the service, and particularly station maintenance. External funding has been given for new stations, but not for the maintenance. Many stations are therefore out of service relatively short after installation. Standardisation of procedures, data management, cooperation and information exchange with neighbours, access to ECMWF data are all deemed as necessary. Better models are needed for the larger watersheds, for the smaller catchments, it might be better to focus on training of the staff than to rely on models where the reliability of the data input will be an issue.

Table 5 Priorities gaps and needs for improved flood monitoring and early flood warning: Albania

	Description	Location or number	Priority
Meteorological stations	Upgrading of the manual stations with sensors (temperature, precipitation, snow depth if necessary).	30	10
Hydrological stations	Upgrading of the manual stations located in the main rivers.	30	10
PCs	Workstations needed for the forecasting room.	7	6
Precipitation radar	One miniradar operational and this are low cost radar. To cover the rest of the territory another 4 miniradars or 1 normal are needed.	4	7
Access to NWP-products	Would like to join ECMWF as member.	1	10
Software for rainfall-runoff modelling	Has SOBEK and MIKE but also need simpler models that request fewer inputs, to be easier applied for flood warning purposes.	1	10
Other software	GIS, data quality control, Windows Server.	3	10
Training	Meteorological and hydrological forecasting, EWS procedures, media communication, data management, modelling.	6	10

Armenia

Armenia is a mountainous and landlocked country in the Southern Caucasus. The country covers 30 000 km^2, and has an average elevation of 1 800 m (range from 375 to 4090 m). The climate is arid and continental, but with high spatial gradients due to the mountainous relief. Average annual precipitation ranges from 250-1 000 mm/year, with an average of 592 mm. The higher regions have snow covers each year, whereas this is not always the case for the lower regions. Two large rivers dominate — Kura in the north and Araks in the south. The country does not have abundant amounts of surface water, but 55-70 percent of the annual discharge occurs in the spring due to snow melt, which can cause damages. Flash floods also occur, commonly observed as mudflows.

The previous Armstathydromet, now a part of The Armenian Hydro-meteorological and Monitoring Service State Non-commercial Organisation is the only organisation in the country which is responsible for hydro-meteorological services. There are 615 employees in Armstathydromet, of which 455 are full time observers. 57 % of the staff has higher education.

The country has 47 meteorological stations, three of these are automatic. There are also 2 automated agro-meteorological weather stations. The stations are also relatively well distributed within elevation zones. However, data from the manual stations are only available in the database after 3-4 months. The network itself is regarded as sufficient, but automatization of collection and data transfer is needed. Quality control is not done in real time, and is based on manual work. There are errors in the time series, and 35 % of historical data is still only available in paper format. Meteorological data from 4 stations are included in global data sets. Data from 12 more stations

Armenia has 95 runoff gauges, of which 4 are automated. The network is regarded as sufficient, but modernization and automatization is needed. Data transfer is mostly by telephone. Rating curves are drafted manually, but regularly updated (25-35 discharge measurements per year). A large number of observations are still only necessary on paper. Historical time series are regarded as reliable though.

Both hydrological and meteorological forecasting is based on expert interpretation of image output of NWP maps from ECMWF, GFS, DWD, NCEP and UKMO. Daily forecasts are produced for 50 rivers, whereas long-term forecasts (decadal, monthly and spring flood) are produced for up to 87 sites. Spring flood modelling are also based on regression modelling. Armstatehydromet is, together with partners, trying to develop an NWP model for Armenia, and to implement a rainfall-runoff model. The service is connected to BSMEFFG, but not to EFAS.

The meteorological network is seen as sufficient, but stations and instruments need to be replaced or modernised. High altitude stations are missing though. Also the number of hydrological stations is satisfactory, but not the number of automatic stations. Implementation of rainfall-runoff models are partly waiting for installation of automatic stations. Many time series have been digitised, but this is ongoing work. The staff would need additional training, partly because the educational institutions are not covering newer developments within hydrometeorology.

Table 6 Priorities gaps and needs for improved flood monitoring and early flood warning: Armenia

	Description	Number	Priority
Meteorological stations	Automated Meteorological Station with standard parameters	5	8
Meteorological stations	Wind sensors with displays	20	10
Hydrological stations	Radar measuring water level gauge	10	10
IT-hardware	Server		10
Precipitation radar	Dual polarisation and Doppler radar	2	10
Access to NWP-products	Integrated workstation dedicated to the forecasting (like Met View) Implementation of limited area small mesh model with 24h operation	Weather forecasting Department	10
Software for rainfall-runoff modelling	for the mountainous rivers	Hydrological forecasting Department	10
Software	to utilise satellite data, numerical rainfall forecasts, hydro-meteorological ground observation data for flood forecasting	Weather forecasting Department Hydrological forecasting Department	8
Software	for preparation of the end product for the media, ready to disseminate		7
Software	for creation of a hydrological database to rescue a large amount of hydrological data		7
Training	On new technologies to be implemented	Weather and hydrological forecasters, data transfer and personnel management	8

Azerbaijan

The Azerbaijan Republic is a mountainous country with an area of 86 600 km^2, but the country also has plains, low-lands and depressions. The elevation ranges from -27 to 4 480 mas. The annual average precipitation ranges from 200-350 mm in Absheron to 16-1 800 mm in the Lenkaran lowlands. There are three main sub-basins in the country; Kura, Araz (large tributary of Kura) and smaller rivers draining directly to the Caspian Sea. Both Kura and Araz have sources outside the country, flowing through Turkey, Georgia, Armenia, Iran. The total watershed area of the Kura river is 188 000 km^2 whereas it is 102 000 km^2 for Araz. Mean annual runoff of Kura is 270 m^3/s, and 121 m^3/s for Araz.

The main floods are connected with snow melting and rainfall. In the higher catchments, most of the floods occur in June-July. In rivers between 1 500 and 2 500 m altitude, flooding is more typical for the period May-June. The lower altitudes are more affected by rain in the spring and the autumn. Many of these are non-perennial rivers, they will in periods dry out completely. An additional problem in some catchments, particularly in the South Slope of Greater Caucasus, is that flooding also lead to mudflows with large amounts of suspended material, causing damages when it is collected in the downstream areas.

Hydro-meteorological observations are carried out by the National Hydro-meteorological Department (NHD), which replaced the former National Hydro-meteorological service. The organisation has a total of 1 633 employees, of which 334 can be classified as meteorologists and 181 as hydrologists. The rest are engineers and management, supporting staff etc. 1 270 persons are connected with the observation network.

There are 72 operational meteorological stations (of which 60 are automatic) and 75 operational meteorological posts (all manual). The meteorological stations observe the variables every 2-3 hours, whereas the posts observe precipitation twice daily and temperature once. The observations are transferred daily (automatic or manually).

NHD has 101 hydrological gauges in rivers, lakes and reservoirs. 44 of these are measured twice a day, and information sent to NHD every morning. The remaining stations are referred to as regime stations, and are only observed 6 times a month.

Quality control procedures are in place for both meteorological and hydrological variables, including semantic checks, statistical controls, neighbour comparisons, and consistency checks when replacing instruments. Most records from the last century (meteorological and hydrological) needs digitising.

There are no rainfall-runoff models in operation. Current hydrological forecasts are based on correlation relationship between hydro-meteorological elements and expert knowledge/analyses of hydrological and meteorological situation and forecasts. NHD is responsible for flood alerts.

Azerbaijan is participating in BSMEFFG. Otherwise, the cooperation with neighbouring countries needs to be improved.

Both the number of operative meteorological and hydrological stations needs to be improved, together with the observation frequency. There is also a need for rehabilitation of existing precipitation radars and installation of new ones.

Table 7 Priorities gaps and needs for improved flood monitoring and early flood warning: Azerbaijan

	Description	Location or number	Priority
Meteorological stations	More operative stations for daily meteorological data More automatic stations with online transfer (currently is about 30). There is a need to digitise old records	50 50 HMC	10 10 9
Hydrological stations	More operative stations for daily hydrological data More automatic stations with online transfer There is need to digitise old records	50 40 HMC	10 9 9
IT-hardware	There is need to develop/purchase and apply: • Hydro-meteorological data base • Data base software • Technical facilities	HMC HMC HMC	9 9 9
Precipitation radar	Need to rehabilitate existing 4 radars and install new ones Online contact with radars	4 Forecast bureau	8 8
Access to NWP-products	Improve weather forecasting system by automatic data processing and forecast systems	Forecast bureau	10
Software for rainfall-runoff modeling	There is need to develop/purchase and apply: • Software for rainfall-runoff modelling • Technical facilities	HMC HMC	9 9
Other software	Other software to be used in flood forecasting processes	Forecast bureau	9
Training	Forecast bureau — hydrologists Forecast bureau — meteorologists IT	10 10 20	10 10 9
Network	Train staff in the hydro-meteorological stations in data processing, data base, GIS tools, different software —hydrologists —meteorologists	40 35	9 9

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Belarus

The Republic of Belarus is a landlocked country in Eastern Europe. The country has a large number of large rivers, many of them transnational. Flooding is common, particularly in spring. The latest large event happened in March 2013, when thousands of buildings were flooded. Flood warnings mainly rely on expert judgement, based on hydrological and meteorological observations and numerical weather forecasts. The current network is not sufficient for flood monitoring and early warning (lack of stations and lack of automatization of existing stations), but the more urgent needs for improved early warning would be implementation of rainfall-runoff models on the major rivers. Better weather forecasts and training of the staff is also high on the priority list, together with new radars.

The country is relatively flat, ranging between 90 and 345 masl, and with an area of 208 000 km^2. The climate is moderately continental, with mild and humid winters, warm summers and damp autumns. Average rainfall is 600-700 mm per year, 70 % falling in the warm period. Winter precipitation will frequently fall as snow. The major rivers in Belarus are Dnieper, Berezina, Pripyat, Sozh and Neman, all but Berezina (flows to Dnieper) are transboundary. The rivers flow to the Baltic Sea and to the Black Sea. The largest lakes are Naroch (80 km^2) and Osveyskoye lake (53 km^2).

There are two centres that are involved in flood monitoring and early flood warning in Belarus. These are Center of Hydrometeorology, Radioactive Contamination Control and Environmental Monitoring of the Republic of Belarus (Hydromet) and the Republican Emergency Management and Response Centre of the Ministry for Emergency Situations of the Republic of Belarus (REMRC). Hydromet is mainly observing hydrological and meteorological variables, and does some meteorological and hydrological forecasting. The Centre has 164 employees within the hydro-meteorological fields, most of them in the observation network. REMRC will receive real time data and meteorological forecasts from Hydromet, and will issue alerts for areas that are likely to be flooded.

Hydromet observed meteorological variables at altogether 113 stations and posts, 37 of them with complete meteorological observations. 36 stations are partly automatic. Observed data undergoes syntactic, semantic and spatial quality controls. Previous records have been digitised. Recent observations from 75 stations are publicly available through the centre’s website. Additionally, Hydromet has 3 noncoherent radar sets available, 20-40 years old.

The hydrological network of Hydromet consists of 109 river gauges, 14 lake gauges and 2 boggy stations. Observations are normally done on daily basis, but frequency increases with necessity during flood situations. 7 stations are equipped with automatic measuring devices, station observers on the remaining stations have to transfer data to the central office by mail, phone or fax. Old records have been digitised. Observed data undergoes syntactic, semantic and spatial quality controls.

Hydromet produces 1-, 3-, and 7-day forecasts, with daily updates for the first two. These are based on national observations together with output from regional large scale models (UK Met Office, GFS and COSMO-RU). Hydrological forecasts are mainly based on expert judgement, a rainfall-runoff model has only been implemented for the Pripyat basin. Based on the forecasts from Hydromet, RERMC forecasts which areas are likely to be flooded for short (daily) and long term (few months). RERMC is also responsible for issuing flood alerts.

RERMC became EFAS partner in 2016 and has good interaction with hydro-meteorological services and civil protection in the neighbouring countries: Russia, Poland, Lithuania, Latvia and Ukraine.

Table 8 Priorities gaps and needs for improved flood monitoring and early flood warning: Belarus

	Description	Location or number	Priority
Meteorological stations	There is a need for additional observation points for precipitation	116	3
Hydrological stations	There is a need for additional hydrological observation points	23	5
IT-hardware			
Precipitation radar		1-2	10
Access to NWP-products			10
Software for rainfall-runoff modelling			10
Other software	The need for continuous updating of hydrological data processing software		7
Training			10

Bosnia and Herzegovina

Bosnia and Herzegovina is a hilly/mountainous country of 51 100 km^2. The elevation ranges from Sea Level to 2 400 mas. The annual average precipitation ranges from 800-1 500 mm. The country has three climatic regions — the maritime belt along the coast (Herzegovina), the alpine belt in Central Bosnia and a moderate climatic belt in Northern Bosnia. Most larger rivers are international, either cross-boundary rivers (tributaries of Drina, Neretva, Una, Korana and Glina) or on the border (Sava, parts of Una and Drina).

Flooding is usually a result of heavy rain, or a combination of heavy rain and snow melt, typically in spring or autumn. Floods are frequently flash flood events. It is quite common that several watersheds peak at almost the same time, and that the flood waves coincides at confluences. The country has recently prepared several preliminary flood risk assessments for some of the major rivers.

There are several agencies involved in flood monitoring and early flood warning in Bosnia and Herzegovina, partly due to the country being divided into two Entities — Federation of Bosnia and Herzegovina (51 % of the territory B&H) and The Republika Srpska (49 % of the territory of B&H), and The Brčko Disctrict. They are also split according to watersheds. The agencies are:

- Sava River Watershed Agency (Sarajevo) — 18 employees
- Agency for the Watershed of Adriatic Sea (Mostar) — 3 employees
- Public Institution Vode Srpske (Bijeljina) — 11
- Federal Hydro-meteorological Institute (Sarajevo) — 68
- Republic Hydro-meteorological Institute of Republika Srpska (Banja Luka) — 70

Altogether, 170 persons are employed in the water sector in Bosnia and Herzegovina — within meteorological monitoring, hydrological monitoring, flood monitoring and early flood warning. The agencies mainly operate on different watersheds, but will in many cases cooperate during flood situations, at technical-advisory level, and advice for important decisions. Some of the agencies also have more formal and permanent contacts.

The station network was dramatically reduced after the war in 1991-1995. Today there are 45 (21 automatic) meteorological stations, some of them only measuring precipitation, temperature and humidity. There are plans to add more automatic stations. Observation frequency is from hourly to daily, with daily transmission to the central offices. There are 133 hydrological gauges, 118 of these have automatic logging with hourly measurements. There are quality checks of both meteorological and hydrological observations, including inner consistency, comparisons with neighbouring stations and when changing instruments. Some historical data still needs to be digitised. Data is available in real time through web page and FTP server. Different summaries of hydrological and GIS data are available to the public.

The meteorological forecasts are separate for the two entities. Two rainfall-runoff models are in operational use; HBV light GUI for the Bosna river basin and HEC HMS in the Una river basin and the Neretva basin. The MIKE rainfall-runoff model is used for the Una River in the Federation of Bosnia and Herzegovina as part of a project. There are also plans to apply MIKE in other basins. These models have daily resolution and have so far not been used during flood events, so flood warnings will still be given partly based on expert judgement based on observations and weather forecast.

Bosnia and Herzegovina is participating in SEFFGS and is also in the process of becoming EFAS partner. The country is also a part of the Sava Flood Forecasting and Warning System, which is under development for all countries in the Sava basin.

There is a need for more meteorological stations, whereas the number of hydrological stations is satisfactory. There is also a need for further development of rainfall-runoff models with higher temporal resolution and for training of both existing and new staff. International cooperation is good and developing, whereas domestic cooperation between the many agencies can still be improved.

Table 9 Priorities gaps and needs for improved flood monitoring and early flood warning: Bosnia and Herzegovina

	Description	Locality or number	Priority
Meteorological stations		140	8
Hydrological stations	Automated hydrological stations with data transfer	13	8
IT-hardware	RAK Server with 64 CPU at least or more.	one at least for each Institutions	6
Radar for precipitation		At least one	8
Access to NWP-products	ECMWF NWP data		6
Software for modelling of precipitation — outflow	Software which shall be agreed as standard at the level of B&H		
Other software	Software for early warning for floods (like MIKE OPERATIONS) Visualisation software for grib, netcdf, hdf5...data.		8
Training	Training for software. Training at job in one of the National Met Service. How to use and run the NWP models. Satellite meteorology.	4	5
Other			

Egypt

Egypt is in the north-east of Africa, bordered by Libya, Sudan, the Gaza Strip and Israel, and with coastline towards the Mediterranean Sea and the Red Sea. The country covers more than 1 000 000 km^2 and has more than 2 900 km of coastline. The altitude ranges from 133 m below sea level to 1 629 m above sea level. The main hydrological feature of the country is the Nile, which floats through the narrow Nile valley in the upper parts, but ends in the large Nile Delta, which covers the last 160 km of the river, and which is 250 km wide at coastline. The climate is semi desert, characterised by hot dry summers, moderate winters, and very little rainfall. However, the rain in North Egypt and Sinai can be moderate to heavy in winter. The annual average precipitation on the coastline is between 100-200 mm, sinking to 0 in the desert areas.

After the completion of the Aswan High dam in 1970, flooding on the Nile has not been an issue. Flooding in Egypt is instead a result of heavy rain, which can occur in the rainy season from October to March, particularly over mountainous areas such as the Sinai Peninsula and beside the Red Sea coast and south valley in Asouit and Aswan.

The Egyptian Meteorological Authority (EMA) is responsible for meteorological monitoring, forecasting and warning. The Ministry of Water Resources and Irrigation is responsible for hydrological monitoring and forecasting. However, as the hydrological threats are more likely to be a direct effect of heavy rain, EMA is also responsible for hydrological warnings. EMA has about 2000 employees, including observers, technicians etc.

The main meteorological network in Egypt is run by EMA, with 112 meteorological stations (70 automatic) and 9 agro meteorological stations, together with 5 upper air stations. MWRI has additionally 40 meteorological stations (30 automatic) collocated with their hydrological stations, but these are not used for meteorological reports, forecasting, and hydrological warnings. All automatic stations report hourly, whereas data from manual stations are collected hourly and reported daily. Data is available from a data base, and some is available online.

The hydrological network of MWRI consists of 40 stations (30 automatic), the largest share on the Nile, on the main distributaries Rosetta and Damietta, and on smaller branches in the delta. Water level is measured every 30 min and reported hourly (automatic) or daily (manual stations). Both meteorological and hydrological observations are quality controlled when entered in the data base, both comparing with neighbouring stations, outlier control and consistency check when replacing or recalibrating instruments.

EMA produces their own meteorological forecasts, based on ECMWF, Cosmo, and with implementations of Cosmo and WRF. MWRI has implemented several rainfall-runoff models, which are used for research and training, and for operative forecasting on the Nile, based on precipitation over Ethiopia and the lake of Tana and from observed discharge. It is not common to make warnings based on hydrological models, mainly because the flood risk from the Nile is rather small because of the Aswan High Dam. EMA is therefore responsible for flood warning, based on forecasts of heavy rain.

To further improve flood monitoring and early warning, there is a need for about 20 more meteorological and hydrological stations, mainly to improve the spatial distribution. It is also necessary to continue upgrading of manual stations with automatic stations. At least 5 radars would also be highly useful. Although the staff number is high, there is a need for staff that is able to improve hydrological modelling and verification, and for optimizing the use of weather forecast and climate forecast models.

Table 10 Priorities gaps and needs for improved flood monitoring and early flood warning: Egypt

	Description	Location or number	Priority
Meteorological stations	Surface meteorology and agro station (AWS). Replace manual stations with AWS.	In west and east desert and south of Egypt — 15-20 new locations	10
Hydrological stations	Automatic stations	At least 20 in River Nile in estuaries and deltas	10
IT-hardware	High performance computer for running models and making model simulations and scenarios Data base	Research department Climate department	8
Precipitation radar	Ideally 5 weather radars	North, South and East of Egypt	7
Access to NWP-products	Training in NWP models statistical models, analysis climate data. Training in how to optimize usage of the WRF and RCM4 models for forecasting and in verification of forecasts.	In forecasting centre and research department	8
Software for rainfall-runoff modelling	Hydrological models for prediction of Nile flood and discharge flow	In research and computing centre	8
Other software	Installing and learn to use R and use it in operational work. In general increase the computer skills, for programming and developing.	Research department	6
Training	Training is necessary, to improve computer skill and for capacity building.	Training Centre and Research department	10
Staff	Increase the staff in NWP and research centre		9
Other	In addition, implement new ozone station and solar radiation stations for atlas radiations	Two in east and west desert	8

Georgia

Georgia is a mountainous country in South Caucasus of 69 700 km2, with 3.7 million inhabitants, excluding Abkhazia and South Ossetia. Only 26 % of the area is under 500m, whereas more than 50 % is above 1 000 m. The Western part drains to the Black Sea with the Rioni River as the largest within Georgia. The larger Central and Eastern part drains to the Caspian Sea, mainly through Kura and tributaries (Alazani is the largest). The country has 170 km^2 of lakes, most of them small. Some larger reservoirs, with 2.4 km^3 total capacity, represent 5 % of the annual runoff. The climate is diverse, with perennial snow and glaciers in the mountains, a humid subtropical climate near the Black Sea, and a steppe-continental climate in Eastern Georgia. The subtropical areas receive about 1000-2000 mm of precipitation per year, where the plains receive on average 500-800 mm. In the period 1995-2012, floods and flash floods counted for 31 % of all hydro-meteorological extreme events (hail and avalanches were also common). About 12 000 km^2 is in Abkhazia and South Osseatia, which is not under control of the Georgian government, and hence not monitored by the National hydro-meteorological service.

The Hydro-meteorological Department (NHMS) of the National Environmental Agency (NEA) is responsible for flood monitoring, observation and collection of hydro-meteorological data in Georgia. The department has a total of 185 employees, of which 96 are related to the observation networks, 15 are involved in meteorological modelling and forecasting and 12 are involved in hydrological modelling and forecasting. Severe weather warnings from NEA are sent to the Emergency Management Agency, which is responsible for further dissemination and for civil protection plans.

The meteorological observation network has 78 precipitation stations, of which 66 are automatic. The automatic stations measure hourly and upload the data to NHMS with the same frequency. The manual stations measure and upload 8 times per day, whereas meteorological posts measure and upload twice per day. Data from some stations is available from website. Quality control is done automatically (through the software Persona MIS) and by an expert.

Hydrological variables are observed at 60 locations, 18 manual and 42 automatic. The automatic stations are new (since 2013-2014), and identification of rating curves is still in progress, hence not all of them are yet used for. Manual stations record and transfer data twice per day, whereas the automatic stations do this hourly. Old records have been digitized, including runoff data from more than 400 closed stations. Quality control is done by experts, but with guidance from the World Data Centre for Meteorology in Obninsk, Russia. Rating curves are updates regularly. The service has produced flood maps for 10, 50 and 100-year return periods.

NHMS receives several regional weather forecasts, and processes these, together with observations, in a standard application of SYNERGIE, developed by Météo France International. Also the Weather Research and Forecasting model is implemented and in use. Georgia is not a member of EUMETSAT, but receives data through EUMENTCast. Forecasting of runoff is still based on expert analysis of meteorological forecasts and observed river water levels. However, there are ongoing projects for implementing Mike Zero and HEC-HMS in two regions. Georgia is also using the Black Sea Middle East Flash Flood Guidance System (BSMEFFG) from WMO, but the forecasts are still not seen as sufficiently reliable for warnings about flash floods. Hydrologists in NHMS have some contact with colleagues in Turkey and Azerbaijan during flood events.

There is a need for several new meteorological and hydrological stations in Georgia. An estimate is that the country should have around 300 meteorological stations and 150 hydrological stations, the same number as available in 1990. Also radars, better access to NWP products and software is necessary. The country also needs more staff, and better training of the staff.

Table 11 Priorities gaps and needs for improved flood monitoring and early flood warning: Georgia

	Description	Location or number	Priority
Meteorological stations	Precipitation stations	about 100 (close to Hydrological station)	10
Hydrological stations	Water level stations	about 100	10
PCs	-	-	-
Precipitation radar	dual polarization *Doppler weather radar*; mini radar	Two, in western and eastern Georgia in non-covered/ mountainous area)	10 10
Access to NWP-products	Aladin update of SYNERGY full package	NHMS head office in Tbilisi	10 10
Software for rainfall-runoff modelling	-	-	-
Other software	Meteofactory system — an integrated early warning solution for the generation and dissemination of weather warning maps	NHMS head office in Tbilisi	10
Training	Rainfall-runoff modelling NWP-products Satellite data processing Radar data processing Meteofactory system		10 8 10 10 8

Israel

Israel is a geographically diverse country with both Mediterranean, semi -arid and arid climate. The original area of Israel is 20 770 km^2, whereas the activities of the Israeli Meteorological and Hydrological Services cover a larger area: (27 400 km^2 including the West Bank and shared basins from Lebanon, Egypt and Jordan). The elevation ranges from -430 m at the Red Sea to 2 200 m in the Golan Heights (the Hermon range). Annual rainfall in Israel ranges from approximately 1 000 millimetres (mm) in the northern mountains (upper Kinneret and western Galilee), to 500-600 mm at the central mountains and the Coastal basin. In the southern Negev and Arava regions the annual rainfall is usually below 50 mm. The majority of rainfall is lost to evapotranspiration (approximately 70 % according to most models), while approximately 25 % infiltrates to groundwater and 5 % flows as surface water. Flood damage is a consequence of flash floods in the desert and urban flash floods.

Meteorological observation, modelling and forecasting is mainly organised under Israel Meteorological Service (IMS), whereas hydrological observation and modelling is organised under Israel Hydrological Service (IHS), under the Water Authority (Ministry of Energy and Water). The services have 60 and 62 employees, respectively.

IMS has around 400 rain gauges in the country. Around 120 of these are fully automatic and transfer observations every 10 minutes to IMS and IHS. There are additional meteorological stations with online observations that are maintained by the Ministry of Agriculture, the Water Authority, the drainage Authorities and others. IHS has on the other hand around 130 hydrological stations which observed every 5 minutes. 50 of these are telemetric. Average record length for meteorological data is 30-50 years, whereas it is 65 years for hydrological data. Quality control procedures are in place, including gap filling for missing values at the end of a rainy season, neighbourhood comparison, and irregular extreme values are examined. Stations might also be revisited.

Forecasting at IHS is mainly done with two models, based on meteorological forecasts from IMS (including ECMWF and COSMO). A fully coupled atmospheric — land surface WRF Hydro model (developed by NCAR) provides 72 hour forecasts for 170 forecast points. HEC-HMS is used for the coastal area, mainly around Tel Aviv. IMS and IHS have recently agreed on procedures for flood alerts, where IHS sends alerts to the Ministry of civil protection after consulting with IMS.

Israel has a relatively good monitoring and modelling capacity, and also cooperation and handling of warnings is good and improving. IHS identifies urban flash floods as the most important event type which they would like to model and monitor better than today.

Table 12 Priorities gaps and needs for improved flood monitoring and early flood warning: Israel

	Description	Location or number	Priority
Meteorological stations		Adding more stations at arid areas and high elevation	5
Hydrological stations		Adding more stations for urban runoff	8
IT-hardware		More storage and CPU	5
Precipitation radar		Adding radar at the south, with the border with Jordan	5
Access to NWP-products	Already have access to all the needed NWP products		2
Software for rainfall-runoff modelling	Urban flooding		8
Other software	Need codes and algorithms for data assimilation into the flood models: Radar, remote sensing		10
Training	Urban flooding, data assimilation		10

Jordan

Jordan is a relatively small country (96 000 km^2), 90 % of the land area is covered by desert. The Northwestern part belongs to the Fertile Crescent. Summers are warm and dry, winters are milder and wetter. The Jordan Valley has a semitropical climate with hot summers and warm winters, the Mountain Heights Plateu has a semiarid climate of Mediterranean type and the eastern desert has hot summers and cold winters. Annual average temperatures are 12-25 ºC and summer highs reach 40 ºC in the desert. Annual rainfall varies from 50-600 mm, from the desert to the northern hills. The elevation ranges from -350 m in the Dead Sea area to more than 1200 m in the mountain heights plateau.

The country has many wadis (valleys, streams, water courses), which can be of different types, perennial with variable flow, perennial with almost constant flow, non-perennial wadis, and spring fed small wadis. The most typical flood type is flash floods, either at the beginning or at the end of the rainy season, during periods of unstable weather conditions. Some flood risk maps have been derived. 10 large dams are used to store water mainly for irrigation, with a total capacity of 325 million m^3.

The water sector in Jordan includes Ministry of Water and Irrigation (MWI), Water Authority of Jordan (WAJ), and Jordan Valley Authority (JVA). MWI is responsible for hydrological monitoring and much meteorological monitoring. The Jordan Meteorological Department (JMD) (Ministry of Transportation) also has responsibilities for meteorological monitoring and forecasting. WAJ and JVA are responsible for water management. Responsibilities are overlapping, but there are shared committees and data exchange, formalised through an MOU between MWI and JMD. MWI has 42 employees, and JMD 194, including 107 observers and 25 in the forecasting centre. JMD has more observing staff than MWI, as frequency of JMD observations are higher and MWI has more telemetric stations.

The country currently has 208 meteorological observation stations at 156 locations. 89 stations are automatic with observation frequency from 20 minutes to 8 hours, 54 of them telemetric. More than 20 stations are only checked once per year. The first observations are from 1930. MWI and JMD have separate databases, both available to internal users. Some (near) real-time observations from JMD are public through a website. Data is quality controlled by MWI and JMD when entered into their respective data bases (WIS and CMDS). JMD used to have a radar, currently not operative. A new one is planned, but skills are missing. MWI, JMD, the Ministry of Agriculture and JVA are planning to install up to 60 new rainfall gauge stations. Historical records have been digitised (except for lost records), but it is still necessary to extract intensity-duration relationships.

52 gauging stations are used to measure hydrological features at 33 locations. 22 of these are equipped with automatic loggers and/or telemetric stations. The first observations were made in the 1930s, and average record length is 30 years. Some stations are only observing monthly. Data is available from the database of MWI. Historic data has been digitised. Data is to some degree quality checked, but data and rating curves are often of poor quality due to erosion, and lack of maintenance of river beds and stations.

JMD makes meteorological forecasts, but lack an NWP-model for the country. Forecasts are based on models from WMO and observations. JMD is also responsible for flood warning, although MWI and JVA are monitoring surface water. MWI had a rainfall runoff model, but not been updated or used for the last 10 years. JMD flood forecasts are therefore based on meteorological forecasts and expert judgement. A pilot of a flash flood early warning system has been installed in Petra, funded by USAID. Jordan has not joined WMO's BSMEFFG, but is considering. Transnational flooding is not likely, but there is still some regional cooperation with neighbours, although limited due to political issues.

The highest priority is a system for flood early warning and flood management. This means both NWP products for Jordan and hydrological modelling tools. It is also necessary to improve the skills of the staff, from basic hydrology to GIS, ICT and English level. The station network for meteorological and hydrological observations seem sufficient with the planned upgrades. There is a need for better maintenance and protection of the stations.

Table 13 Priorities gaps and needs for improved flood monitoring and early flood warning: Jordan

	Description location or number	Priority
Meteorological stations	Upgrade of manual and semi-automatic stations to be telemetric and adding weather stations nearby the 10 dams	6
Hydrological stations	Maintenance for the locations of the existing stations and upgrading them to telemetric ones Stations protections Installing new 5 stations at different sites	8
IT-hardware	Upgrading computers and servers	6
Precipitation radar	Not relevant	1
Access to NWP-products	Numerical weather prediction models specialised for Jordan is needed	7
Software for rainfall-runoff modelling	This kind of modelling tools is urgently needed Example: MIKE basin and any others	9
Other software	ArcGIS licenses from ESRI	7
Training	Training is very necessary in the following fields: of technical and mechanical fields related to weather stations, English command, surface water modelling, Hydrology basics, standard monitoring procedures, general computer skills, GIS, database maintenance and web based solutions, telemetric monitoring principles, quality control procedures, land surveying for wadis	10
Flood early warning and flood management	Flood early warning system, flood management procedures and guidelines, and flood management legislative framework Better coordination between legal entities related to floods Flood risks maps for all Jordan and flooding risk reduction plans specially for urban flooding	10

Kosovo

Kosovo is a country of 1.8 million inhabitants and almost 11 000 km^2, located in the central part of the Balkan Peninsula. The country has borders with Serbia, Macedonia, Montenegro and Albania. The landscape is characterised by the high peripheral mountains and low central mountains on one side (63 %), and the hollows, plains and valleys on the other side. The climate is Mediterranean and Continental, with an annual average temperature of 10.4 ºC, ranging from -1.3 ºC in January to 19.2 ºC in July. The annual average precipitation varies between 600-800 mm. The most damaging floods are flash floods, in some cases in combination with snow melt.

Kosovo can be referred to as the peak of the 'Balkans', with rivers draining to three sea basins through one of the neighbouring countries: The Adriatic Sea (White Drin), The Aegean Sea (Lepenci) and The Black Sea (Morava e Binçës and Ibri). Almost all rivers in Kosovo also originate within Kosovo. The total catchment area of rivers in Kosovo is 11 645 km^2, only 6.5 % more than the country's area.

The Ministry of Environment and Spatial Planning (MESP) is the competent authority for water management in Kosovo, and has key responsibilities within water resources, waste, forests, air quality, managing and planning of development. The Kosovo Environmental Protection Agency (KEPA) is a part of MESP, and includes The Hydro Meteorological Institute of Kosovo (KHMI), which is responsible for all hydro-meteorological activities in Kosovo. 22 people are employed by KHMI.

The meteorological observation network consists of seven automatic meteorological stations and around 20 manual precipitation gauges. The first ones have a high observation frequency (hourly), whereas the manual gauges are only observed once per day. Data from three of the automatic stations are transferred hourly, whereas the remaining four are only transferred daily. Data is not properly quality controlled because of a lack of skilled staff. Historical records are only available in pdfs of annual yearbooks. Maintenance of the manual gauges has been a huge problem.

The historical hydrological network was relatively well distributed, with 33 stations being observed every morning. Some stations also had limnographs. After the war, it took some years to build up the network again, which now has 28 gauges. Seven of these are connected with GPRS and record water levels every 15 minutes, while the water level is recorded every hour in the remaining 21 stations. Historical data has been digitised and quality controlled. The institute also sees the quality control of post-war observations as sufficient. Rating curves are updated, but the frequency could be better, currently it is from zero to a few measurements per year.

(Meteorological forecasts): Hydrological forecasting in Kosovo is mainly based on expert judgement from analysing forecasts and the hydro-meteorological observations. However, a hydraulic flood modelling system for the Drini basin has been implemented in a research project, and there is the intention to use this model also operationally. The forecasts from KHMI is public and given to media. The Emergency Agency is then responsible for potential emergency operations.

Kosovo is a partner of EFAS, and has a relatively good cooperation with most of the neighbouring countries, partly through a joint project for the Drin basin. There is a also a joint project with The former Yugoslav Republic of Macedonia for the Lepenci river.

KHMI is in a challenging situation both when it comes to financial resources and the staff situation. The institute depends on funding from MESP/KEPA, and there is currently no budget line for maintenance, which has led to rapid loss of stations after installation. There is also a lack of specialists in both meteorology and hydrology. Additionally, there is a lack of meteorological stations and one more hydrological station. Better access to NWP-products would also be helpful.

Table 14 Priorities gaps and needs for improved flood monitoring and early flood warning: Kosovo

	Description	Location or number	Priority
Meteorological stations		Giljan, Malisheve, Leposavi, Drenas	10
Hydrological stations		Giljan	9
IT hardware		Pristina	5
Precipitation radar		Kleqka	7
Access to NWP-products		Yes	8
Software for rainfall-runoff modelling		HEC-RAS, MCH, Panta Rhei	5
Other software			
Training			5
More staff			

The former Yugoslav Republic of Macedonia

The former Yugoslav Republic of Macedonia is a landlocked country in the southeast part of Europa, in the central part of the Balkan Peninsula. The country borders with Bulgaria, Serbia, Albania and Greece. The total surface are is 25 713 km^2, and the population is around 2 million people. The country is mainly mountainous with some flat valleys, three bigger natural lakes, and a dense river network. The climate is also mountainous, with a continental to variable continental climate in the lower parts. The summers are hot and dry, and the winters colder. The average precipitation varies from 500 mm in the east to 1 700 mm in the western mountains.

All catchments in the country are draining out of the country, mainly to the Aegan Sea through the Vardar River (catchment area 20 442 km^2). The second largest basin within the country border is the Crn Drim, which forms a part of the Drin Basin, draining to the Adriatic Sea. Many types of flooding can take place, but the worst consequences are typically from flash floods and urban flash floods. Some simple flood risk maps have been developed, but the country is still in need of proper maps.

The National Hydro-meteorological Service (HMSM) is responsible for both meteorological and hydrological matters, including development of the observation network, monitoring, meteorological and hydrological research and applications. The service has 191 employees, 84 of these connected to the monitoring network. 14 persons are employed within the hydrological department, within observation (8), groundwater (2) and hydrological forecasts (4). Hydrological alerts are issued by HMSM to the Crisis Management Center, which will then organise a Steering Committee, which will be responsible for the crisis management.

The meteorological monitoring network consists of 19 main meteorological stations (16 with automatic recorders), and additional networks of climatological stations (7 operational), rain gauges (101) and phenological stations (24). Only the meteorological network has a sufficiently high frequency of observations (10 min for automatic/every 3 hours for manual) and data transfer (hourly/twice per day) to be used for hydrological warnings. Data is quality controlled. There are also two operational radars, but these are old and have some problems with maintenance and lack of spare parts and engineers. There are some private measurements, which should be transferred to HMSM, but there are still negotiations about how to do this efficiently.

The hydrological observation network was historically more dense than today, with up to 110 stations. From 1961-2000, around 50 stations were recording with limnographs, whereas this number has further decreased afterwards. 65 stations are currently operational, 33 of these have limnographs (old type) after a renewal process in 2001, 28 of these are currently working. There are also 6 operational automatic stations. Out of 18 stations installed in 2004 and 2008, only one is still in use. Data quality procedures are in place, but suffer from a lack of staff.

There are no proper rainfall-runoff models in use, but the country has good experience with a grapho-analytical method. However, this has not been updated since a while, and is currently less in use. Forecasting and warning is therefore mainly based on expert analysis of the hydrological situation and the forecasted precipitation. The country also uses SEEFFGS and EFAS products. In general, the country has good cooperation with the neighbours.

The main needs are more stations, particularly automatic, and an increased number of staff.

Table 15 Priorities gaps and needs for improved flood monitoring and early flood warning: the former Yugoslav Republic of Macedonia

	Description	Location or number	Priority
Meteorological stations	New stations on higher altitudes with rain, snow, temperature, soil temperature and humidity	Minimum 20 new stations + 60 automatic	10
Main meteorological stations	New automatic stations with rain, snow, temperature, soil temperature and humidity	11 stations on existing locations	10
Climatological stations	New automatic stations with rain, snow, temperature, soil temperature and humidity	7 on existing locations	10
Hydrological stations	Revitalisation of the hydrological network, and new stations on higher altitudes	Minimum 20, preferably 80, including automatic	10
IT-hardware	Separate servers for hydrology and meteorology departments from main HMSM server	Hydrological and Meteorological Departments	6
Precipitation radar	Revitalise the two existing radar stations Short range radars (30-60 km)	2 normal radars 7 short range radars	8
Access to NWP-products	Improve precipitation forecast and monitoring. HMSM should also upload more data to WMO.	HMSM	4
Software for rainfall-runoff modeling	For bigger river catchments: Upper Vardar, Treska, Lepenec, Pcinja, Bregalnica, Crna, Strumica, CrnDrim.	HMSM — Hydrological Department	6
Other software	DataBase & Data Management Hydrological Software (HydroPro or WISKY …)	HMSM — Hydrological Department	6
Training	O&M, how to work with the software	HMSM — Hydrological Department	6
Staff	New engineers: hydrologists, meteorologists, synoptic engineers, radar engineers, IT engineers …	HMSM	10
Cooperation Crisis Management Centre	Modernisation and Continuous service and O&M in Regional Centres of CMC Change the 35 Regional Crisis Management Centres (RCMC) for local level to 8 main RCMC and 27 smaller RCMC to cover 85 municipalities	CMC	8
Other	Computers, servers and other equipment	CMC	8
Other	Better cooperation between Crisis Management Centre (CMC) and Protection and Rescue Directorate (PRD)	CMC PRD	10
Other	Modernisation in Protection and Rescue Directorate (PRD) Computers, equipment for rescuing, vehicles, water pumps, professional rescue teams.	PRD	8

Moldova

The Republic of Moldova is a relatively small, landlocked country in the central part of Europe, between Ukraine and Romania. The main rivers are Dniester and Prut, both draining towards the Black Sea, partly through the Danube. Both of them are transnational rivers. The climate is moderately continental, with short, mild winters (average -4 °C) and long hot summers (average 20 °C, could reach 40 °C). Precipitation is in the range of 500-650 mm annually. The average elevation is low (147 m, maximum 430 m), but the landscape is characterised by many hills and hartops (valleys) between them.

Large floods have taken place in the past on the main rivers, with devastating effects for example in 2008 and 2010. There are also frequent flash floods in the smaller rivers. Usually floods take place during spring and summer.

The State Hydro-meteorological Service (SHS) is responsible both for meteorological and hydrological observations and forecasting. The service has 353 employees, including 173 persons involved with the monitoring network. There are 15 and 13 persons working with Meteorological and hydrological modelling and forecasting, respectively. There is also a large group working with environmental quality monitoring (64).

The meteorological observation network has recently been upgraded, and now has 14 automatic weather stations and 35 automatic posts (measuring precipitation and temperature). Weather variables are measured every 10 min-30 min, and transferred to the main office hourly or every three hourly, or at time of precipitation. Observations started in 1944 and average record length is around 50 years. Moldova also has a new radar, and produces some gridded data of the weather variables, based on observations. Some old data still needs to be digitised, newer data is quality controlled and to some degree available through (non-OGC) websites.

The hydrological observation network consists of 46 stations, 31 of them with automatic recording. Data is transferred twice per day. The network is split in two parts, managed by two centres. These are currently responsible for the Northern and the Southern part of the country, respectively, but it is planned to reorganise these, according to basins (Prut and Dniester) instead. Data is quality controlled, and new observations are also available online. Historical time series are of reasonable quality, but about 30 % has not yet been digitized. The first records are from 1878, but average record length is 25-30 years.

The Meteorological Forecast Centre develops synoptic charts from a combination of output from numeric large scale models of DWD, ECMWF, UK MetOffice, NCEP, JMA and others, together with the meteorological observations (stations and radar). A national NWP model is missing, but there is ongoing work to implement one. SHS does not have any rainfall-runoff models. Hydrological forecasts are therefore based on weather forecasts and hydrological expert judgements. Moldova is a member of both SEEFFG and EFAS, has good relationships with the neighbours, and is also a member of The Black Sea Group and The Danube Convention.

With the recent updates of the meteorological and hydrological networks, these are close to satisfactory, although a few more hydrological stations (10) would be useful in addition to replacement of old and broken stations (10). The needs regarding observations are more urgent when it comes to data transfer, as the stations come from different projects, and read and transfer data in different ways. SHS would also like to have web-cams at the stations, showing rivers and river banks. For better predictions, a national NWP model would be useful, in addition to rainfall-runoff models. The staff number is sufficient, but it is necessary to improve skills. The most urgent need rather the infrastructure for the two planned hydrological centres, following the main watersheds. It has been difficult to get funding for this.

Table 16 Priorities gaps and needs for improved flood monitoring and early flood warning: Moldova

	Description	Location or number	Priority
Meteorological stations	Improve data transfer, i.e., quicker control and transfer, more consistent types of data	14 AWS + 32 mini AWS	10
Hydrological stations	Improve data transfer, i.e., quicker control and transfer, more consistent types of data	46	10
Hydrological stations	Mainly on tributaries of Dniester and Prut rivers, and replacement for old and broken gauges	20	8
IT-hardware	Numerical models and secured servers for data bases.	1+1	10
Precipitation radar	An evenly distributed network of mini radars all over the country's territory is needed.	10 mini radars	8
Access to NWP-products	No national NWP currently exists	1	9
Software for rainfall-runoff modelling	Rainfall-runoff models needs to be implemented for Prut and Dniester rivers	2	8
Other software	Software for rating curve construction, analysis of data flow quality and software for real time visualization of data and river bed area (webcam)	1 for each	10
Training	Mandatory for software use but also hardware	At least 2 per year	10
Equipment	For measurement of maximum flow (e.g. Rio Grande) For real time visualisation (web cam) of rivers and river banks.	1 46	10 10
Constructions	Two basin centres ([20]) on Prut and Dniester rivers.	2	10

([20]) Centres for management of the hydrographical basin: collection and data flow management from these catchments, including maintenance and full service of all posts attributed to the specific river basin.

Montenegro

Montenegro is a partly mountainous country on the Balkan Peninsula, with an area of 13 800 km^2. Rivers drain to the Adriatic Sea in the Southwest, and towards the Black Sea in the North, Northeast. 15 percent of the territory is above 1 500 m. The mean annual precipitation is 1500 mm, ranging from 1 100 mm in the mountainous regions in the North to 4 600 mm in a village in the coastal zone (maximum 15 km from the Adriatic Sea). The most severe flood types are the large riverine floods, often occurring in transnational rivers.

The Institute of Hydrometeorology and Seismology (IHMS) is responsible for both hydrological and meteorological observations, forecasts and analyses. The Institute has 117 employees within six sectors, including air and water quality, seismology and hydrography and oceanography. 54 of the employees work with the observation network, 14 with data management. Six persons are involved with weather modelling and forecasting, whereas three are employed in the Department of Hydrological Analysis.

Montenegro has 45 operational meteorological, climatological and precipitation stations. 15 of these are automatic. Temporal resolution is mainly three per day for manual stations and 10 minute intervals or more frequent for the automatic stations. Manual data is transferred to the main office up to three times per day for most of the main stations and only monthly for the climatological stations, whereas automatically sampled data is transferred every ten minutes. Quality control of the data follows a three step procedure: Manual check by observer, Manual check by technician in main office, and by using the methods implemented in the CLIDATA database. The country has interpolated maps of precipitation and SPI.

IHMS currently has 22 operational hydrological stations, all of these are automatic. They record hourly and report daily. The service does not regularly receive other observations of water levels, but hydropower producers and others who operate structures along the rivers have to provide daily reports. Quality control follow a similar procedure as for climate data. Consistency is checked when changing measurement device. Discharge is measured 4-6 times a year for controlling the rating curve.

No rainfall–runoff model is currently in use, but the PANTHA RHEI model is being tested for the Drin basin. Otherwise the service relies on expert interpretation of weather forecasts and the current water levels. A set of forecasts are received from NCEP and ECMWF, which are further processed by WRF-NMM. IHMS is a partner of EFAS, but does not use the Flash Flood Guidance System of WMO. Cooperation with neighbouring countries have recently improved, and exchange of data is supporting early flood warning on transboundary rivers.

Flood alerts from IHMS are sent to the Ministry of Interior, Sector for Emergency Management, which alerts the public and sets up an operational team for the crisis management.

The network of meteorological stations is regarded as sufficient, but the number of precipitation stations should increase from 17 to at least 50. More stations should also be replaced with automatic observations, and also automatic data transfer. Some evapotranspiration pans would also be useful.

The hydrological network should be further extended. A plan from 2006 identified 51 locations where stations would be needed, up from the 22 automatic stations today. At some locations it is not possible to measure discharge during flood events.

Table 17 Priorities gaps and needs for improved flood monitoring and early flood warning: Montenegro

	Description	Location	Priority
Precipitation gauges	need automatic stations	Lim river basin — 5 stations Moraca river basin — 5 stations Tara river basin — 5 stations	Moraca — 10 Lim — 10 Tara — 5
Temperature stations	need automatic stations	Lim river basin — 5 stations Moraca river basin — 5 stations Tara river basin — 5 stations	Lim — 10 Moraca — 10 Tara — 5
Runoff gauges	need automatic stations	Lim River, Ibar River, Tara River, Piva River, Cehotina River	Lim River — 10 Tara River — 10 Ibar River — 10 Piva River — 8 Cehotina River — 8
PCs	Desktop computers Servers, Cluster for modeling	Institute for Hydrometeorology and Seismology of Montenegro	IHMS — 10
Software	Upgrade of the existing WISKI database and staff training	Institute for Hydrometeorology and Seismology of Montenegro	IHMS — 10
Precipitation radar	Precipitation radars on remote terrain where it is impossible to set up stations	2 radars in the remote areas of Montenegro	9

Morocco

The Kingdom of Morocco covers 450 000 km^2 in the North-western corner of Africa, bordering the Atlantic and the Mediterranean Sea. The country has four distinct regions; a fertile coastal plain along the Mediterranean, the coastal plains in the West, the Atlas Mountains and semiarid grasslands south of the Atlas Mountains. The Atlas range include 10 peaks around 4 000 m. Annual precipitation ranges from less than 50 mm/year in the desert to more than 800 mm in the North. Rivers drain both to the Atlantic and the Mediterranean Sea, and a few rivers on the South side of Atlas also drain into Sahara. The highest flood risk comes from flash floods, and there has been several events during the last 15 years with dozens of casualties. As part of a flood protection plan, 391 sites have been identified as vulnerable to floods.

The Water department is responsible for both meteorology and hydrology in Morocco. It has four directorates, of which the Directorate for Research and Planning for Water (DRPE) and the Directorate of National Meteorology (DMN) are the responsible for flood warning and flood monitoring. There is also a directorate for water projects, more related to dams and flood protection structures. There are 9 Hydraulic Basin Agencies, responsible for 22 watersheds. The Water Department has 2424 employees, of which 1 071 are technicians and 497 engineers. 747 work in the DNM, the rest within the water related directorates and in the administration.

The meteorological observation network of Morocco was recently upgraded from 44 manual stations to 200, of which 156 are relatively new automatic stations (2013). These are transmitting data with high frequency (minutes) to the water department. The older manual stations are transferring less frequent, and also there are old records which are still only available on paper. There are also around 400 pluviometric stations near the rivers under the responsibility of DRPE, of which 240 have automatic gauges in addition to the manual. Morocco also has six weather radars, covering the Northwestern and central part of the country. However, they need maintenance.

The hydrological observation network is the responsibility of DRPE and the hydraulic basin agencies. The current network has 265 gauges, of which 140 have automatic logging. The automatic are logging continuously, at manual stations the runoff is recorded once per day. A part of the flood warning network is referred to as the flood warning network, and consists of 54 posts at dams, 140 posts at hydrological stations, and 23 posts at pluviometric stations. These report to a central monitoring system at Rabat, where flood risk is assessed. Little information was given about quality control, but it seems that improved methods would be useful.

DNM produces national weather forecasts on 2.5 km resolution from AROME, in addition to other models, such as ALBACHIR, ALADIN-NORAF and large scale outputs form ECMWF and ARPEGE. The forecasters also use satellite images from MeteoSat Second Generation.

There have been some tests of rainfall-runoff models, but none of these have been taken into operational use. Both statistical modelling (through ANN) and numerical modelling (Soil Conservation Number and Snowmelt Runoff Model). However, an increasing number of Moroccan basins are equipped with early warning systems, in particular Ouergha, Bouregregn, Ourika, Rheraya, Souss, Loukkos and Ziz. The system consists of telemetric stations, fast analyses of experts, dissemination through internet and possible evacuation alerts through radio, sirens and speakers. Morocco is member of ANBO (African network of Basin Organisations) and MEMBO (Mediterranean Network of Basin Organisations).

In addition to more meteorological and hydrological stations (both new locations and upgrading to automatic gauges), there is room for improvement for flood forecasting. First of all, models are needed, then it is necessary to give more training to the staff for hydrologic modelling. Other possibilities for improvement is better cooperation between hydrological and meteorological units, including better use of the rainfall forecasts. Also communication during and after floods can be improved.

Table 18 Priorities gaps and needs for improved flood monitoring and early flood warning: Morocco

	Description	Location or number	Priority
Meteorological stations	Increase the number of meteorological stations around the rivers		7
Hydrological stations	Increase the number of hydrological stations		7
IT-hardware	Enhancing the performance of existing computing tools for NWP use.		6
Precipitation radar	Maintenance of existing radars	Six existing radars	3
Access to NWP-products	Hourly availability of other international NWP-products, in particular rainfall		2
Software for rainfall-runoff modelling	Development of rainfall-runoff models for all the Moroccan catchments even if some of them are not frequently affected by floods		6
Other software			
Training	Training of staff about the new technology and operational methods uses in other countries affected by floods		6

Serbia

Serbia is situated in the central part of the Balkan Peninsula (South Eastern Europe) with a territory of 88 361 km^2. Serbia borders with Hungary (North), Romania (Northeast), Bulgaria (East), the former Yugoslav Republic of Macedonia and Albania (South), Montenegro (Southwest) and Bosnia & Herzegovina and Croatia (West). Northern Serbia is mostly plain, while its central and southern parts are mostly mountainous, up to 2,656 m in the mountain range Prokletije. Around 55 % of the Serbian territory is arable land, while about 27 % is forested. The climate is continental, with average winter temperatures around or below zero, and summer temperatures close to 30 degrees. The rainfall is mainly around 700-800 mm, but can reach 1 000 mm in the mountains. The highest monthly precipitation is in the summer months, particularly June, as a result of thunderstorms.

Rivers belong to the catchments of the Black Sea, the Adriatic Sea and the Aegean Sea. Three of them, the Danube, the Sava and the Tisa are navigable. The Danube is the longest river (2 857 km), of which 588 km is in Serbia. Flood risk and flood hazard maps have been developed for the Danube and Morava river.

The Republic Hydro-meteorological Service of Serbia (RHMSS) is responsible for meteorological and hydrological monitoring, weather and hydrological analysis, forecast and early warning, climatology and monitoring and prediction of climate change. It has 288 employees altogether, of which 200+ are associated with the observation network, 42 in weather modelling and forecasting, and 8 in hydrological modelling and forecasting. The Sector for Emergency Management, Directorate for Water and Public Water Management Company, are responsible for the implementation of flood control. In terms of emergency situations, the Sector for Emergency Management is responsible for evacuation and rescue.

The meteorological network has 458 stations, only 28 of these are automatic. The manual stations observe 3 times per day (53 stations) or once per day (390 stations). The automatic stations record hourly or every 10 minutes. Additionally, Serbia is covered by 15 Doppler dual polarisation radars (two composite radars for the entire territory and 13 local), and RHMSS has a radio sounding station. Most of old data has been digitised. All data is available in an internal database. Data is quality controlled through several tests. RHMSS has also implemented the Quality management standard-QMS ISO 9001:2008.

The hydrological network consists of 180 manual stations and 95 automatic stations. The automatic stations are collocated with manual stations, hence the total can be regarded to be 180 stations. Automatic stations measure every hour (10 minutes in some cases) whereas observations at the manual stations are taken once per day. RHMSS updates the rating curves with flow measurements at 50 stations every month. Observations are available on the website of RHMSS and in data base. All data have been digitised.

Several models are used for forecasting for different rivers. For the large ones, it is mainly a combination of statistical methods and river routing. For small and medium catchments, the HBV model is applied. For catchments without models, the forecasts relies on expert judgement by experiences hydrologists. Several weather forecast models are used, including global models (ECMWF, DWD, NMMB) and limited area models (WRF Europe, WRF Balkan, NMMB Europe, NMMB Balkan and ETA). Flood alerts are issued by RHMSS and forwarded to media, public and relevant governmental institutions. During flood situations, RHMSS has relied on Copernicus services for satellite disaster monitoring.

RHMSS has been an EFAS partner since 2008, and is included in WMO's SEEFFG system since 2013. The country also has bilateral agreements with Romania and Hungary, and member of the commissions for the Danube river and the Sava River. Serbia is also a partner of the Sava Flood Forecasting and Warning System (Sava FFWS).

The main need in Serbia are more automatic stations, particularly in mountainous regions, both meteorological (around 50-60) and hydrological (around 30). The service sees itself as understaffed, but well educated. More staff would be necessary to be able to implement and run more and better rainfall-runoff models, such as Mike Flood model. New servers are necessary in the head office.

Table 19 Priorities gaps and needs for improved flood monitoring and early flood warning: Serbia

	Description	Location or number	Priority
Meteorological stations	New automatic precipitation stations	Mountain regions	10
Hydrological stations	New automatic hydrological stations	Mountain regions	10
IT-hardware	New working stations (mini servers)	Head office in Belgrade	9
Precipitation radar			
Access to NWP-products			
Software for rainfall-runoff modelling	Mike Flood model	Head office in Belgrade	9
Other software			
Training	For new hydrological model	Head office in Belgrade	9

Turkey

Turkey is a large and geographically diverse country, covering 780 000 km^2 with 2 949 km land borders and 7 816 km coastline. The neighbours are Greece and Bulgaria (West), Georgia, Armenia, Azerbaijan/Nakhichevan and Iran (East), and Iraq and Syria (South). There are high mountains along the Black Sea coast in the north and the Mediterranean coast in the south. The country has 120 natural large lakes and 555 large dam reservoirs. Most of Turkey's transboundary rivers originate in Turkey, with Kura-Aras basin the most important watershed in South Caucasus.

The climate is overall semi-arid. The southern coast has a Mediterranean climate with hot, dry summers and mild, rainy winters. The northern coast has a Black Sea climate — mild and rainy in almost all seasons, up to 2 500 mm annually. The Central Anatolia features a relatively dry steppe climate (less than 250 mm annually) with high daily and yearly temperature variability. Approximately 70 % of total precipitation falls from October to March. Snowfall occurs on average from 1-40 days per year.

Floods are well recorded: 2 563 floods took 1 496 lives in the period 1955-2014 with annual economic loss around USD 100 million. Damaging overbank flooding is most common, together with flash floods.

The hydro-meteorological services are mainly administered by three agencies:

- The General Directorate of State Hydraulics Works (DSI), responsible for hydrological network, including observations and forecasts; plan, design, construction and operation of dams, hydroelectric power plants, domestic water and irrigation schemes.
- The General Directorate of Water Management (SYGM), responsible for basin management, flood and drought management at the basin scale and associated water laws.
- Turkish State Meteorological Service (TSMS) — responsible for meteorological network in Turkey, including observations, forecasts and climatological data.

Both TSMS and DSI observe meteorological variables. TSMS has almost 1 400 stations, 10 upper air stations and 16 radars, all automatic, with measurement frequencies 30 minutes — daily. DSIs network is less automatized, has around 200-250 stations for snow, precipitation and temperature with hydrological stations. DSI has 910 automatic gauging stations with daily observations. Data is quality controlled, historic time series are digitized.

TSMS produces and has access to a range of meteorological forecasts, which is transferred to DSI on a real-time basis, but with limited use for flood forecasting and early warning. DSI has implemented a coupled atmospheric-hydrological model for the Kızılırmak basin, with WEHY as the hydrological component. Also the transboundary Maritza river basin has a real-time flood forecasting and early warning system. For other watersheds forecasting is based on expert judgement. Other rainfall-runoff models are not used for operational forecasting. The Flash Flood Guidance Systems for South-East Europe (SEEFFGS) and Black Sea and Middle East (BSMEFFGS) has been installed in the offices of TSMS. The system should cover the entire country, but there are still some issues.

Flood alerts can be raised by local (majors, governors), regional (DSI, TSMS) and national authorities (DSI, TSMS, AFAD), published by TSMS in meteorological warnings. The warnings will be on radio, and sent to relevant authorities via phone and email. A challenge is that the link between available early warning information and actions taken is moderate.

The cooperation with neighbouring countries is from good (Greece, Bulgaria) to very limited (eastern and southern borders). There is some exchange with Georgia due to Turkish use of Georgian hydropower and Armenia due to water allocation from Arpacay River.

The most important needs in Turkey for better flood monitoring and early flood warning are more radars, better access to NWP-products for central and regional offices of DSI and the civil protection agency, and better training. New hydro-meteorological stations would be useful in mountainous regions of the country.

Table 20 Priorities gaps and needs for improved flood monitoring and early flood warning: Turkey

	Description	Location or number	Priority
Meteorological stations	Flash flood gage network Flood forecasting and early warning system	Mountainous topographies- specifically along the Black Sea and Mediterranean The first phase can include an estimated 50 stations.	8
Hydrological stations	Flash flood gage network Flood forecasting and early warning system	Mountainous topographies- specifically along the Black Sea and Mediterranean The first phase can include an estimated 50 stations.	8
IT-hardware	Compatible hardware systems at the Headquarters and Regional Directorates of DSI and TSMS	25 river basins in Turkey	8
Precipitation radar	Existing radars: Maintenance and operational readiness are critical Proposed radar: To be strategically located to minimise information gaps due to the geographical boundaries	25 river basins in Turkey	9
Access to NWP-products	Use of real-time NWP products developed by TSMS, implemented in the concept of real-time decision support systems at the Headquarters and Regional Directorates of DSI and AFAD	25 river basins in Turkey	9
Software for rainfall-runoff modelling	Use of grid-based rainfall-runoff models developed through integration of the physical processes (i.e. snow melt) and other spatial parameters of high importance (i.e. soil moisture)	25 river basins in Turkey	7
Other software	To be evaluated by the regional and headquarters organisations of DSI and TSMS.	25 river basins in Turkey	6
Training	Training and capacity building in meteorological and hydrological forecasting and transitioning these products into flood forecasting and early-warning systems	25 river basins in Turkey	9

Ukraine

Ukraine is in the Eastern part of Europa, with borders towards Russian, Belarus, Poland, Slovakia, Hungary, Romania and Moldova. The country also has a coastline towards the Sea of Azov and the Black Sea. The total area is more than 600 000 km^2 and is mostly flat, except for the Crimean Mountains in the South and the Carpathians in the west. The annual average temperature is 7-9 ^oC, with slightly higher temperatures in the south. The winter temperatures are on average below zero, except for Crimea. Average summer temperatures are in the range 18-12 ^oC. Most of the precipitation is caused by cyclones and atmospheric fronts, and ranges annually from 450 mm in the south to 700 mm per year in the west and north-west. The highest levels are observed in the mountains.

The largest river of Ukraine is the Dnieper river, with a length of 2 200 km^2 and a catchment area of 520 000 km^2, (1 121 km and 292 700 km^2 is in Ukraine, respectively). There are also other large rivers, such as Desna, Pripyat (these are two large tributaries of Dnieper of the first order), Dniester, Southern Bug, Tisa and Siverskyj Donets. Most of the large rivers are transboundary.

Flooding is frequent in one or more of the catchments. These includes most types of flooding, such as snow melt floods, rain floods and mudflows. Also ice jams are a concern in the mountainous regions, giving quick rises of water levels. A range of flood protection measures have been installed during the last 20 years, including earth dams and bank stabilization. There are also several reservoirs, which can be used for flood protection, although most of them have other purposes (water supply, irrigation, fish farming, hydropower). However, it is not sufficient for full protection. Flood maps have been developed for some regions.

The Ukrainian Hydro-meteorological Centre (UHMC) within the Ministry of Emergencies is the main responsible for hydro-meteorological activities in Ukraine. The service has around 2600 employees, including 1600 in the meteorological section and 300 in the hydrological section. There are additionally around 500 observers. Much of the forecasting takes place in regional centres in each of the 22 oblasts (counties), which will then transmit warnings to the central office of UHMC, depending on basin responsibilities. Population is then informed by local authorities, through mass media and official sites. Hydrological prediction takes place in 9 hydro-meteorological offices, according to basin responsibilities.

Ukraine has 187 meteorological stations and 312 meteorological posts, mainly measuring precipitation and temperature. 45 of the stations have automatic logging. Measurements are taken every 3-6 hours and immediately transferred to the central office. The posts are located in conjunction with some of the 435 hydrological stations (375 fluvial and 60 lacustrine). Of these, 333 are used for flow measurements. 63 of them are automatic. Quality control procedures for both meteorological and hydrological observations exist, but are currently undergoing further development.

UHMC creates their own weather forecasts, based on forecasts from NOAA, KNMI and DWD, using the WRF-model, but Ukraine does not have access to forecasts from ECMWF. Hydrological forecasts are based on models, mainly conceptual box models that predict the runoff based different types of runoff generation, altitude and landscape-hydrological features of the catchments, in addition to the meteorological forecasts. In addition, the Mike11 model is used for some water sheds. Ukraine is a member of EFAS, WMO, and has relatively good cooperation with the neighbouring countries. There are previously signed contracts between the Ukrainian and the Russian hydromet, carried out by both countries.

The main need for improved flood warning and monitoring is new meteorological and hydrological stations, in addition to precipitation radars. About 50 % of the hydrological equipment needs immediate replacement. The country has several hydrological models, but also these are old, and UHMC would like to increase the use of models like MIKE, HECRAS and LISFLOOD. Training is needed, and takes place constantly. Language is a barrier for training abroad.

Table 21 Priorities gaps and needs for improved flood monitoring and early flood warning: Ukraine

	Description	Location or number	Priority
Meteorological stations	Carpathians, Polesia	200 precipitation 100 temperature	10 5
Hydrological stations	Carpathians	100	10
IT-hardware	Stations distant from the station's centre	80	5
Precipitation radar	Carpathians, Black Sea region	5	10
Access to NWP-products	Covering the territory of Ukraine and Europe		10
Software for rainfall-runoff modelling	Hydrological models for individual catchments such as, for example, MIKE 11, MIKE 21, MIKE SHE, HEC-RAS,LISFLOOD	UHMC	8
Other software	ArcGIS	UHMC	8
Training	needs training	most experts	8
Staff	provided by specialists	-	8

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